REPORT

OF

Committee in Charge of the Experiment Station

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

For the Year Ending September 30, 1923

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TABLE OF CONTENTS

	Page
Report of Committee	3
Report of Director	5
Entomology	10
General	10
Leafhopper	10
Borer Beetle	11
Anomala Beetle	13
Armyworms	13
Aphis	14
Wireworms	15
Rat Control	15
Other Work	17
Cane Pathology	18
Root-Rot	18
Mosaic	18
Eye-Spot	19
Leaf Disease of the Tip Canes	20
New Disease in H 463	20
Sectional Chlorosis	21
Deterioration in Yellow Caledonia	22
Forestry	22
Hawaii	22
Oahu	24
Maui and Kauai	26
Nurseries	26
Arboretums	27
Sugar Technology	28
Annual Synopsis of Mill Data	28
Weekly Mill Reports	28
Commercial Sugar Reports	28
Factory Inspections	29
The Filtering Qualities of Hawaiian Raw Sugars	30
Clarification Investigation	33
Miscellaneous	38
Soil Investigations and Allied Projects	39
Research Work	39
Effects of Fertilizing Salts on Hawaiian Soils	41
The Tolerance of H 109 Cane for Heavy Applications of Nitrate of Soda and Ammonium Sulfate	41
A Study of the Phosphates in the Island Sugar Soils	42
The Availability of Potash in Hawaiian Soils	43
The Carbon Content of Plantation Soils	44
Study of Changes in Available Plant Food	44
Root-Rot Investigation	44
Further Observations of Backward Ratoons on Kauai	46
Investigation of the Use of Water at Waimanalo	47
Cooperative Field Experiments	49
Sugar Cane Varieties	53
Hawaiian Seedlings	53
Resistance to Disease and Adverse Conditions by Hardy Sugar Cane Types	58
The Identification of Cane Varieties	63
Improvement of Cane Varieties by Bud Selection	65
A Comparison of Bud Selected Strains	72
Substations on Oahu	74
Waipio Substation	74
The Waipio Field Work	75
Manoa Substation	76
Field Experiments on Hawaii, Kauai and Maui	77
Cooperative Work with Plantations of Hawaii	77
Cooperative Work with Plantations of the Kohala District	79
Field Experiments on Kauai	82
Cooperative Field Work with Plantations of Maui	84
Pineapple Work	91
A Study of Composition of the Pineapple Plant	91
Growth of Pineapples in Nutrient Solutions	91
Miscellaneous Laboratory Analyses—Pineapple Work	91
Essential Factors of Sugar Production — Sugar Cane Growth Values	92
Publications	113
Additions and Changes of Staff	113
Appendix	115
Laboratory Work	115
Fertilizer Control Work	115

Report of Committee in Charge of the Experiment Station

Honolulu, Hawaii, October 23, 1923.

To the President and Members of the
Hawaiian Sugar Planters' Association,
Honolulu, Hawaii

Gentlemen:

Transmitted herewith is the report of the Director of the Experiment Station covering in detail the work of the Station for the year ended September 30, 1923. You will find this report very complete and of great interest.

We desire to call particular attention to two important matters in connection with the Experiment Station which were accomplished during the year which has just closed. The first of these was the reorganization of the staff so as to separate the work in plant pathology from that in forestry and botany, creating two departments to handle these different subjects. After careful consideration it was decided that Dr. Lyon would retain the work in forestry and botany, and with the additional time which will be at his disposal the forestry problems will now receive the attention which their importance deserves. The Committee regrets the resignation during the year of Dr. L. O. Kunkel, whose work here was very promising. Arrangements have been made with Mr. H. Atherton Lee to join the staff in November of the present year, and another pathologist will also be engaged. Every effort will be made to make this department as strong as is possible.

The second matter to which attention is drawn is the importation during the year, with the permission and under the supervision of the Board of Agriculture and Forestry, of four varieties of Java cane. These canes were grown in quarantine in Washington, D. C., shipped from there by Dr. Kunkel, examined and passed upon arrival by Mr. Muir and Dr. Lyon of the Station staff and by representatives of the Board of Agriculture and Forestry. They have been planted in a quarantine house at the pathology plot in Alexander Street, and will be grown in quarantine under close observation for at least one year.

The total expenses of the Station, including the Waipio substation, for the fiscal year ended September 30, 1923, amounted to $274,596.64. During the fiscal year which ended September 30, 1922, these expenses were $227,827.38.

The members of the committee feel that the Station's work during the past year has been increasingly valuable to the plantations and wish to take this opportunity of expressing their appreciation of the hard and conscientious work done during the past year by the Director, the department heads and all members of the staff.

Respectfully submitted,

T. H. PETRIE, Chairman;
HORACE JOHNSON, Member;
WILLIAM SEARBY, Member;
P. BARTELS, Member;
W. VAN H. DUKER, Member;
C. R. HEMENWAY, Member.

Director's Report

Honolulu, T. H., September 29, 1923.

To the Experiment Station Committee,
Hawaiian Sugar Planters' Association,
Honolulu, T. H.

GENTLEMEN:

A report of the work of the Experiment Station for the year ending September 30, 1923, follows:

The developments of the year tend to show that the leafhopper is now in complete subjection, controlled as it is by the egg-sucking bug *Cyrtorhinus mundulus*, discussed in the reports of the previous years. Such doubt as still remains on this point should be cleared within another year, in the opinion of Mr. Muir.

Actual measurements made of borer damage indicate that the loss from this pest, while very low compared with former times, is still an appreciable one in certain districts. Mr. Muir is endeavoring to secure additional natural enemies through Mr. Osborn and Dr. Williams who are working in Mexico and South America. There are some encouraging developments in this connection, but no new parasites have actually become established as yet.

The introduction of some hardy canes which in other countries have reduced borer damage to a great degree also offers interesting possibilities in this connection.

The Anomala beetle continues at a very low ebb and while the area of infestation has spread about a mile since the introduction of the *Scolia* parasite in 1916, the numbers to be found are so small that Mr. Muir and Mr. Swezey consider the control entirely satisfactory from a commercial standpoint.

Work proceeds on the projects of obtaining natural enemies for wireworms, cutworms and aphis. The latter as a carrier of mosaic disease in sugar cane and other grasses assumes importance and deserves special attention.

Important enemies of the cutworm have been secured from Mexico by Mr. Osborn, and from Calfornia by Mr. Timberlake. Dr. Williams has reached British Guiana after exploring Ecuador in search of wireworm parasites.

Our forestry problems are in part botanical. Some very promising plant material has been imported. These problems are partly questions of forest reserve management, fencing, policing, protecting the native flora where it thrives, and supplementing it with hardier species where it fails. Over and above these considerations the forestry issue becomes an educational program in bringing the population and interests of Hawaii to realize that the watersheds are an all-important asset, and that they must be cared for in a businesslike way.

Dr. Lyon is now to give his entire time to forestry work. He has the cooperation of Mr. Bryan who is supervising the well organized Hilo Forest Reserve as well as the small Halawa-Niulii Reserve which is also well supported, Mr. McEldowney who is working with him to establish an appropriate reserve in the Koolau Mountains of Oahu, and Mr. Forbes who handles the work of the Vineyard Street Nursery. A number of plantations on Kauai with individual watersheds are receiving planting material from us. The same is true of Hawaii and Maui. Dr. Lyon has recently investigated forestry conditions on Maui.

Our problems in connection with sugar cane diseases are still serious ones, but the situation, as we saw it a year ago, shows some improvement. The poor condition in many fields of Yellow Caledonia on Kauai in 1922 was in part seasonal and that variety has done better this year. But this has not altered the belief on the part of many that Yellow Caledonia shows evidence of weakness and must decline in area in favor of canes that ratoon more vigorously. H 109 in irrigated districts shows great resistance to root-rot, and concern felt early in the year that this malady was making an inroad upon this variety has been modified by strong growth made in the late spring and summer in affected areas. Evidence has been secured that the trouble in this field was due, at least in part, to phosphate starvation.

In connection with studies of root disease, much interest is found in the investigations of Hoffer and Carr of Indiana, who attribute root rots in corn to an excess of active alumina and iron. There are many interesting correlations between the Indiana work with corn and the local experience with cane and the subject is being studied carefully by Mr. Stewart and Mr. McGeorge, who find that cane root growth is affected by the presence of alumina salts to a degree not heretofore realized. It is too early to offer deductions from these investigations, though we have an interesting clue which will be closely followed.

The work of Dr. Lyon and Dr. Kunkel, locally, and that in Washington by Dr. E. W. Brandes, of the U. S. Department of Agriculture, has added to our information regarding sugar cane mosaic and we now know that this disease can be transmitted between some fifteen or twenty species of grass and that in addition to the suppression of the aphis and the use of resistant varieties, the control of certain weeds deserves consideration. Miscellaneous crops of corn and certain forage crops near cane areas are to be discouraged where this is feasible.

The Tip canes, despite the fact that they are susceptible to a leaf disease which is peculiar to them and that they are extremely sensitive to mosaic, continue in favor on account of their vigor at high elevations and cool localities. We must handle them with great caution and consider that they must be ultimately replaced by canes of stronger disease resistance and equal merit on other scores. Such canes will probably come from their hybrids. The D 1135 has been crossed with Striped Tip and Yellow Tip, apparently to good effect.

The investigation in bud selection has reached the stage of a well organized cooperative project. Many plantations are proceeding with this work under the advice and assistance of Mr. Shamel, who spent several months in the Islands in 1923 and will, we expect, be able to make another visit here next year.

Of those engaged in the work there are a number who are confident that by painstaking and persistent selection work, as described in another part of this report, cane varieties can be improved.

In our seedling work special attention is being paid to crosses with disease resistance in view. An effort will be made to clear some of our propagations of a few years ago of the canes which have little or no commercial promise. Mr. Verret, Mr. Pratt and Mr. Kutsunai bring out the need of a rapid elimination of the poorer canes at an early date. They contend, very rightly, that to fail to do so results in losing sight of the good ones for years and, furthermore, limits the number of seedlings that can be grown to too small a number.

Mr. McAllep as head of the Sugar Technology department has had cooperation from Messrs. McCleery, Brodie, Cook, Smith and King.

There have been thirty-two mill inspections during the year. Commercial sugar reports, omitted in 1922, have again been

issued this year. The standard of the sugar, as a whole, has been better than in any previous season.

Important research work has been conducted.

Through the investigations of Walter E. Smith we now know that the difficulty in filtering raw sugars is due to cane wax. It is extremely gratifying that this perplexing question has been settled so promptly. The research showed, to begin with, that the filtering qualities of the sugar were influenced by the amount of fine suspended matter which would pass through a closely woven linen cloth and yet be held upon an asbestos mat in a Gooch crucible. This finely divided suspended matter has recently been found to consist almost entirely of the wax of the cane. In considering ways to improve the filtering qualities of raw sugars, Mr. McCleery and Mr. Smith discuss the probable benefits from increasing polarization, improving clarification and the disposal of settlings and, finally, controlling the reaction of raw sugar solutions previous to filtration at the refinery.

The clarification investigations by H. A. Cook offer precise data on this subject. He finds that the temperature at which juices are held, rather than the degree of alkalinity, is the important factor in sucrose destruction. It follows that the degree of liming should be governed by the temperatures and the duration of time at which juices are to be held. The influence of heat in reducing alkalinity is greatest for juices of high alkalinity. It is found, however, that a juice of high alkalinity remains alkaline for a longer time than one of low alkalinity. The work also deals with the actual effect of sodium carbonate and sodium bicarbonate when used in clarification along with lime. The accuracy of the determination of hydrogen-ion concentration is being investigated.

Mr. Verret reports a satisfactory year at the Waipio substation, which harvested its largest crop this year, and where the investigations are divided between promising seedlings, bud selection endeavors, and experiments bearing upon the profitable limits of intensive agriculture.

In the cooperative work with the plantations a number of experiments have been harvested, substantiating in a general way the deductions previously announced on methods of fertilization and cultivation.

The production of a large number of seedlings has characterized the work in Kohala handled by Mr. Jennings, while on

Kauai the selection of seedlings of earlier propagations has been given special attention. Mr. Broadbent, on Maui, has been active in bud selection work and seedling testing.

A number of fertilizer and cultivation experiments, and bud selection work as well, have been handled in all these localities and where the plantations request it we are prepared to render further service in laying out tests along these lines.

Soil surveys have been made in the cases of several plantations, and this analytical work has contributed materially to the detailed knowledge of Hawaiian sugar lands and the proper way to handle them.

Much of this work has been handled for Mr. Stewart by Messrs. Hansson, Crutchfield, and Van Brocklin. They have also taken care of a large amount of fertilizer control work and miscellaneous analyses.

The work of the plantations, with which Mr. Pemberton has been cooperating, tends to show that the control of field rats on a commercial scale is entirely feasible when the undertaking proceeds under scientific control.

This control work goes into the extent and frequency of poison baiting, the composition of the materials with a view both to potency and palatability, and economical methods of preparation and distribution. Centers of plague infection in rats where they have occasionally occurred have been closely followed and in this phase of the work Mr. Pemberton cooperates with the Territorial Board of Health.

Mr. Swezey has represented the Association at the second scientific congress of the countries about the Pacific held during the past summer in Australia.

Twigg Smith, in his work as Illustrator for the Station, has taken up a study of the Jeswiet identification characters of cane varieties and has made many drawings applying this important Java investigation to our cane variety work. Not only is the means afforded of positively identifying any seedlings, by the minute and almost microscopic hair groups of the buds and certain leaf areas, but the system, which is akin to the Bertillon or thumb-print identifications in man, goes further and offers a way in many instances to trace the parentage of seedlings. The work promises to be very helpful in our cane breeding.

In following the study of the essential factors of sugar production, with special reference to their mathematical interrelation, the writer has made an investigation of the value of growing-time of the different months of the year. Sugar cane growth calendars have been prepared for the purpose of displaying, graphically, the findings that have been made.

These calendars show the growth of a year in terms of 360 growth degrees. This total is divided between the months, according to the potential growth value of each.

From these calendars—there are several to represent a range of circumstances—the proper cropping cycles can be determind. A three-year period can be divided into two crops with due regard to seasonal differences in growth. Thus, instead of having two crops of eighteen months, we find that cycles of 17 and 19 months, 16 and 20, 19 and 17, or 20 and 16, are often the correct divisions of a 36-month period when we take due account of the fact that into some crops winter months enter twice, and in others summer growth values are repeated.

The next step in developing this mathematical analysis of sugar production will be to take data representing the conditions of individual plantations and study irrigation, fertilization, and the use of labor in conjunction with the seasonal growth values.

It is probable that practical benefit will result from this new way of viewing the basic resources of a plantation, for it affords a clearer insight into fundamentals than we have heretofore had.

Entomology

(From a report by Fred. Muir)

General

Progress has continued along several lines of work during the past year. Several valuable beneficial insects have been imported and liberated, and others which were liberated previously have been recovered in the field, so that we know they are now established. Although during the last twenty years the Station has accomplished a great deal in entomology, yet there still remains a lot to do. By following the methods which have proved of such value in the past, I believe a lot more can still be accomplished.

Leafhopper (*Perkinsiella saccharicida*)

The chief feature of the leafhopper situation has been the scarcity of the leafhopper during the greater part of the year.

At no time since the leafhopper was first recognized as a pest in the Islands have our plantations been so free from them. In certain localities where leafhoppers have persisted and periodically increased to considerable numbers they are at present exceedingly scarce. This satisfactory condition is due to the egg-sucking bug (*Cyrtorhinus mundulus*) imported from Australia which has become established on all the islands, and is now found on all plantations wherever a few leafhoppers can be found. One small colony was sent to Kauai and although leafhoppers were scarce at the time, it is now well established on that island. No colony was sent to Maui, yet it found its own way there and is now well established in several places. The great reduction of the leafhopper has led to a reduction of the egg parasites, more especially of the smaller species (*Paranagrus*). But this has been more than compensated by the work of *Cyrtorhinus*, which attacks the young hoppers as well as the eggs.

Over large areas leafhoppers are so scarce as to be practically absent and so no parasites are present. If leafhoppers should get into such areas their increase will depend entirely upon the ability of *Cyrtorhinus* to find them out and get in their work quickly. Should *Cyrtorhinus* show its ability to follow the leafhopper closely, then we shall have no further trouble with the leafhopper, but a condition similar to that found in Australia will have been established, and we can then write "success" across our twenty years of work upon this subject. By next spring we shall know if this be so or not and it will be of great interest to watch the leafhopper condition till then.

Borer Beetle (*Rhabdocnemis obscurus*)

The introduction of the Tachinid parasite (*Ceromasia sphenophori*) into our islands brought about a great reduction of the beetle borer in all localities and in some of the areas which were once badly infested it has held the borer in complete, or nearly complete, control. In some fields where conditions are not so favorable to the parasite, the borer is still an important factor. At Paauhau plantation, a number of counts have been made during harvesting to show the percentage of sticks attacked by borer, and the weight and quality of the juice of these sticks have been compared with sound cane so as to arrive at an idea as to the total loss of sugar due to various percentages of infestation. The average on a large number of counts shows that for every 1 per cent of cane sticks infested by borer there is a loss of sugar amounting to .073 per cent.

During the year Mr. Pemberton has examined 13,400 sticks of cane at Honokaa and found that 26 per cent of them were damaged by borer. These counts were made in different fields during the harvesting and did not take into account sticks killed out by the borers. Applying the Paauhau percentage of loss to the Honokaa crop for the last five years, Mr. Pemberton shows the following results:

From the fact that counts at Honokaa during 1922 in all of the harvested fields show an average of 26 per cent borer infestation, we may reasonably assume a 25 per cent average infestation yearly for the past five years. From Mr. Elliott's analyses at Paauhau a 25 per cent borer infestation gives an average sugar loss of 1.82 per cent. For the five-year period (1918-1923), Honokaa Sugar Company produced 31,579.7475 tons of sugar. Assuming a 1.82 per cent sugar loss from a 25 per cent borer infestation there would have been obtained, had there been no borer damage, a total of 32,165.1532 tons of sugar. This shows a loss of 585.4057 tons of sugar through poor juices owing to borer injury. The average price of sugar over this period was 7.88 cents per pound. The total loss is therefore $92,258.93.

While these figures are recognized as only giving an approximate estimate of the loss, they are of great value as they show that we are still suffering a loss from borer in spite of the good work done by the Tachinid fly, and it behooves us to try to reduce this loss by every means possible. In fields in which borer is bad early harvesting and burning off may be of assistance, but it will be a more satisfactory solution if we can procure other parasites to help control the borer more effectively.

Mr. H. T. Osborn was given a year's leave from the Station to work for the Board of Agriculture and Forestry in Mexico on certain mealybugs, scales and armyworms. His contract with the Board of Agriculture and Forestry expired at the end of June, when he returned to the Experiment Station staff. He was then requested to remain in Mexico and work on several problems, the borer beetle being one of them. He soon discovered a beetle (*Sphenophorus incurrens*) working in the sugar cane and found that it was attacked by a Tachinid fly. This beetle is fairly closely allied to our cane borer, so the parasites were sent along for us to experiment with. Several small shipments have been received and experimented with and some have been liberated in the field. It is too soon to say what will be the result. Mr. Osborn has also found a second beetle (*Metamasius carbonarius*) in the sugar cane which is more nearly allied to our borer than is *Sphenophorus incurrens,* but it is so scarce that he has not been able to find parasites on it yet. He has also found two wasp parasites on *Sphenophorus incurrens,* but so far in too

small number to allow us to experiment with. The work is promising and should be continued.

Anomala Beetle (*Anomala orientalis*)

The satisfactory condition of this beetle, reported last year, has continued during the year and nowhere has it caused any damage to cane. Mr. Swezey has been over the infested area and found very few grubs or beetles. Since the introduction of the *Scolia* parasite in 1916 the *Anomala* has extended its range for about one mile mauka. The hope once expressed that this beetle might be exterminated by the *Scolia* has not been realized, as a few can always find refuge under trash and in other localities and so escape destruction. But the *Scolia* holds it in complete economic control. In cultivated areas the *Scolia* makes considerable impression on *Adoretus* (Japanese beetle), but in grass lands and garden lawns the *Adoretus* escapes the parasite.

With the permission of the Oahu plantation, Dr. J. F. Illingworth collected a number of *Scolia* and shipped them to New Jersey early in the summer, where the U. S. Bureau of Entomology experimented with them on the green Japanese beetle which has become such a serious pest there.

Armyworms

Armyworms were very numerous in many parts of the islands this year. From Honokaa to Hilo nearly every field of young cane was infested and in some places considerable damage was done to the young cane. At Honokaa a mixture of Paris green (1 part) and finely powdered air-slacked lime (8 parts) dusted over the leaves of young cane was found effective. By partially filling a sugar sack with the mixture and shaking the closed bag over the cane the dust was evenly and thoroughly distributed. If young fields are closely watched and the application made as soon as the young armyworms appear this method is very effective.

But the seat of the trouble generally lies in the adjoining grass lands where the armyworms breed all the year round and from where they migrate into the cane lands when the young cane is coming up. If we can cut them off there the trouble would be greatly reduced. The two parasites already in the islands do good work, but their forces want augmenting. Mr. Osborn, when working for the Board of Agriculture and Forestry and since his return to the Station staff, has been working on this problem and has found six or seven different enemies of armyworms in Mexico. The most promising are two species of flies and four species of wasps. One of the wasps

(*Euplectrus* sp.) we have bred in large numbers at the Station and up to date we have liberated 23,000. The Board of Agriculture and Forestry has also bred this in numbers, most of theirs being liberated in ranch lands. A small colony of the larger Tachinid has been liberated. The smaller Tachinid is a very promising parasite and it was very unfortunate that the only large colony Mr. Osborn has been able to get was during the very hot season; during the journey from Mexico to San Francisco and on to Honolulu they all hatched out and died. But we hope to get more at a later date.

We have also been experimenting with a large Carabid beetle which does good work on armyworms in California. Numbers of these were introduced years ago in our islands by Koebele, but they all disappeared. Some observations on the condition of the egg tubes of this beetle indicate that it is possible that we have introduced them at the wrong time of the year. With this in mind we hope to do further work with them; perhaps it may be necessary to get them over in the larval stage.

The armyworm is a more serious problem with the cattle ranches than it is with sugar plantations and I think the ranches should give it more consideration than they have hitherto done. The mynah bird has been of great value in keeping this pest down and in some large plantations and ranches it would be of value to grow a few large trees (such as banyan or other fig trees) in which they can nest and sleep and so be kept in the neighborhood.

Besides the parasites found by Mr. Osborn in Mexico, others are known. In Australia there are two good parasites and in other countries others are known. There is every reason to believe that if time and attention were devoted to this subject the pest could be reduced by some 75 per cent.

Aphis

The green fly or Aphis on cane has been with us for many years and during the months of June to September it has often increased on young cane to such an extent that the growth of the cane has been checked. Eventually they are overtaken by their natural enemies, such as the ladybug, lace-wing flies and syrphid flies.

Until recently the corn aphis, which is quite distinct from the sugar cane aphis, has been considered as of no account in our cane field because although an occasional one is found on cane, it does not breed there. But recent work on mosaic or yellow stripe disease carried on by Brandes, Kunkel and others, has demonstrated that this disease is carried from corn and grasses,

where the corn aphis breeds, to the sugar cane. It therefore becomes of major importance to our industry.

Mr. Timberlake, when on leave in California, spent considerable time in investigating aphis and their enemies with the result that he forwarded several parasites on corn aphis and other species. It is too soon to say what the results of this will be.

Both Dr. Williams and Mr. Osborn will devote some time to this subject.

Wireworms

Dr. Williams has had a strenuous time in Ecuador searching for wireworm parasites, which so far has not been compensated by success. He visited the eastern portion of Ecuador, where traveling is difficult and more than uncomfortable, and he would have proceeded down the Amazon to Brazil but found the transportation of baggage impossible. He therefore returned to the coast and proceeded to British Guiana via the Panama Canal. Although he did not succeed in his chief search for wireworm parasites, he procured interesting collections of insects on sugar cane in those regions and sent over a number of seeds of trees which may be of value in our forestry work. Besides the wireworm problem he will work on the borer and other problems in British Guiana. He is in touch with many of the sugar estates there and so we shall learn more about the entomological conditions there than we know at present.

Rat Control

Mr. Pemberton has spent most of his time on Hawaii checking up the rat damage and rat control work which is being carried on at Honokaa. He has visited other plantations on Hawaii in connection with this work and also checking up borer damage. In connection with rat control, he reports as follows:

In every field harvested during 1923 on Honokaa plantation there has been considerably less rat damage to the cane, and rats everywhere are much less numerous and less frequently seen than in any previous year in the history of the plantation, according to every interested as well as disinterested individual with whom I have conferred. I have discussed this with the laborers, contract bosses, small contract farmers, field and section lunas, skilled employees of all ranks on the plantation, residents at Honokaa, employees directly concerned in the rat campaign, and the manager. From the experience and observation of every one, the opinion, in varying degrees, is the same. From actual estimates made in the field we have only the counts made by the Honokaa Sugar Company in 1922 to show us what the damage amounted to prior to the general control by poisoning. These figures, published on page 173 of the April, 1923, issue of the Planters' Record, showed an average damage in the 1922 crop of 19 per cent. The counts which I have

been making this year in every field harvested at Honokaa since January 5 to date, show an average damage of 3.88 per cent. These fields were all poisoned thoroughly, from two to three times mostly, during their period of growth in 1922-1923. The estimate is still incomplete, for the harvesting will continue for a few weeks more, but the bulk of the crop is off and 3.88 per cent will be close to the final figure. So far the estimate has been made from an examination of a total of 351,100 sticks taken in all sections of each field as it was harvested. The count covers the entire harvested area fairly closely and should give a rather accurate figure on what the damage has actually amounted to since the poison campaign was inaugurated. This average of 3.88 per cent damage for 1921, taken from fields which had all been poisoned, as against 19 per cent for the unpoisoned crop, indicates a large saving and fully justifies the Honokaa Sugar Company in adopting a systematic policy of rat control by poisoning in the future. The bait used was mostly the barium carbonate or "Rat X" cake, but a good deal of strychnin-wheat has also been used this year.

Another poison bait which gives much promise is a dry mixture of rolled grain and barium carbonate. This appears, in controlled experiments inside, to be more attractive to rats than the paraffined "Rat X" cake and its use may be more generally adopted in the future, if the field use of it continues favorable. In laboratory experiments this mixture has been highly effective. It is made by mixing about 1 part barium carbonate (dry) to 6 or 8 parts of rolled oats or rolled wheat. The fine, powdery barium carbonate mixes easily and thoroughly with a rolled grain and sticks to it. This mixture is then put up in small one-third to one-half ounce paraffin paper torpedoes. It is easily carried, easily distributed and rats not only favor it, so far as present observation goes, but certainly carry it away to their nests to some extent.

Though the favorable condition of the Honokaa fields harvested this year proves the effectiveness of the "Rat X" cake, it is hoped that other and more attractive and easily found baits such as the crushed-grain barium carbonate torpedo, described above, may be a still further improvement.

During the past year I have completed 269 separate poison experiments on live rats in cages, testing a long series of baits. Virus baits were very unsatisfactory. Strychnin, phosphorus, arsenic, extract of squill, cyanide of potassium and barium carbonate were tested in various ways. Very poor results were had with the squill mixture in any strength. Arsenic, cyanide and phosphorus were found deadly but difficult to disguise so as to be eaten by rats. Strychnin and barium carbonate have given by far the best results, though with strychnin there has been a wide variation in results. A good many rats have been caught which ate the usual strychnin-wheat in quantity without results. Others, the majority in fact, usually die within twenty-four hours after eating one-third ounce or more of strychnin-wheat. Strychnin-wheat is readily taken by most rats and mice. Barium carbonate seems to be the most deadly to rats of all the poisons experimented with. The bulk of the experiments have been to apply it in some bait palatable to rats. So far the dry crushed or rolled grain mixture seems to be the most attractive.

Other Work

Apart from the direct value of any beneficial parasites sent over by Messrs. Osborn and Williams, their work has been of great value. We know very little of the entomological conditions in the sugar cane in Mexico and Central and South America and it is of importance that we should. With the increase of traffic between these Islands and the Panama Canal, and with the reduction of time in transit between these places, the west coast of Mexico and Central and South America are brought nearer to our door and we must be prepared for cane enemies from those regions. In this respect the information acquired by Messrs. Osborn and Williams on the moth borer and its parasites will be of value to us.

While working for the Board of Agriculture and Forestry, Mr. Osborn sent over parasites for some of our mealybugs which were handled by Mr. Fullaway. One of these has cleaned up the alligator pear mealybug (*Pseudococcus nipae*) very effectively. This mealybug was one of the commonest in Honolulu covering our alligator pear trees, banyan and other fig trees, and many other plants. Its presence in such numbers was used by several visiting entomologists as evidence that our trees were as heavily, or even more heavily, infested than elsewhere in spite of our work with parasites. The discovery and introduction of this parasite (*Pseudophycus utilis*) is a very creditable piece of work even if there be no great financial value attached to it, and due credit must be given to the Board of Agriculture and Forestry and to Mr. Osborn. It adds another page to our list of successfully introduced parasites.

The Federal government has also taken a hand in the introduction of parasites into our territory. Mr. H. F. Willard, of the U. S. Bureau of Entomology in Honolulu, has been breeding and distributing parasites on bean weevils which he brought back from the States some time ago. He has not yet reported on the final outcome of this work, but the parasites have made a decided impression on some species of bean weevil.

An introduced plant known locally as Pamakani (a native of Mexico and Central and South America) has become quite a pest on some ranch lands. Both Dr. Williams and Mr. Osborn have been written to about it and they will investigate with a view of finding insects which may keep it in check in a similar manner as the introduced insects keep lantana in check. The introduction of insects injurious to plants is a delicate matter and no move will be made to introduce anything until a thorough investigation has been made and permission of the Board of Agriculture and

Forestry has been secured. Whatever information Messrs. Osborn and Williams can secure will be towards this end.

My faith in the use of parasites to control insects in these Islands has in no way diminished, but quite the reverse. I believe that if we continue along the lines that have proven so successful in the past, and use every precaution to avoid the dangers which are always connected with this work, we can bring about an ideal entomological condition in these Islands. But the work requires judgment and time and cannot be unduly rushed, and every precaution must be taken that we do not undo any of the good work of the past.

The usual plantation inspections have been carried out during the year and a number of special inspections also made. The handling of the imported parasites has absorbed a large part of the time of the entomologists in Honolulu.

The Station collection has grown in size and scientific value and more shelf space has become necessary. Considerable time has to be devoted to the classification and arrangement of these collections, and specimens which come in from various parts of the world for identification. In return for this we send specimens elsewhere for identification.

Mr. Rosa has devoted most of his time to breeding *Euplectrus,* which he has done in a very efficient manner.

Cane Pathology

(From a report by H. L. Lyon)

Root-Rot

Well defined cases of root-rot have occurred in Yellow Caledonia, Yellow Tip, D 1135 and H 109 in various parts of these Islands. The disease is evidently quite prevalent in other cane-growing countries also, for it has received much attention of late from pathologists in Java and the West Indies. The most remarkable seedling cane of Java, E. K. 28, has proven very susceptible to root-rot.

Mosaic

Prior to his departure for the mainland, Dr. Kunkel prepared a comprehensive paper on the mosaic disease of sugar cane in which he describes in a most thorough manner the symptoms,

transmission and deleterious effects of this malady. He also gives detailed analyses of the data obtained from the several field experiments which he conducted on sugar plantations on Oahu, Maui and Hawaii. The exact information afforded by this paper should aid materially in the practical control of this disease in our cane fields.

From the results obtained by Dr. Kunkel and other investigators of sugar cane mosaic, we may conclude that the spread of the disease in the field is due almost entirely to the corn aphid and that if this insect could be eliminated, mosaic would disappear from our fields. It follows, therefore, that any reduction in the aphid population should work a corresponding reduction in the prevalence of mosaic. This aphid does not breed on the cane plant and only visits it by accident. If we can detect the host plants on which it does breed and reduce their numbers, particularly in the vicinity of our cane fields, we may reduce mosaic to a problem of minor importance.

The mosaic virus which infects sugar cane is now known to thrive in the grasses named below, which are either cultivated to some extent in Hawaii or are more or less common as weeds. All of these grasses are agreeable hosts to the corn aphid:

Cultivated grasses:

Corn.....*Zea mays*, L.
Sorghum.....*Andropogon sorghum*, Brot.
Pearl Millet.....*Pennisetum glaucum* (L), R. Br.
Sudan grass.....*Andropogon sorghum sudanensis*, Piper.
Tunis grass.....*Andropogon sorghum virgatus* (Hack.) Piper.
Guatemala grass.....*Tripsacum laxum*, Nash.
Wonder forage grass. *Andropogon* sp.

Weedy grasses:

European crab-grass..*Syntherisma sanguinalis* (L), Dulac.
Yellow foxtail.....*Chaetochloa lutescens* (Weigel), Stuntz.
Prickly foxtail.....*Chaetochloa verticillata* (L), Scribn.
Barnyard grass.....*Echinochloa crusgalli* (L), Beauv.

Mosaic and corn aphids have been observed on the two grasses named below, which occur as weeds in our cane fields and we have every reason to believe that they harbor the same virus as that affecting cane, although this has not been definitely proven by experiments:

Goose grass.....*Eleusine indica* (L), Gaert.
Native crab-grass.....*Syntherisma pruriens* (Trin.), Arthur.

Eye-spot

Early in November, 1922, eye-spot appeared quite prevalent in H 109 in protected areas on Oahu. It spread considerably dur-

ing December and January, and by February had reached a rather high concentration on certain small areas on the plantations of the Oahu Sugar Company, the Waialua Agricultural Company, and the Waimanalo Sugar Company. Fortunately, the weather during the months immediately following did not favor its rapid spread and the cane came through the winter without suffering serious damage from the disease.

Leaf Disease of the Tip Canes

This disease, described for the first time in our report of last year, has continued to spread on the Tip canes in the Kohala district, but, to the best of our knowledge, has not yet appeared outside of this district. Thus far, it has limited its attack to the Tip canes and one seedling, Kohala 56. It is caused by parasitic bacteria which gain entrance to the tissues of the leaves, bringing about their destruction. Infection usually progresses lengthwise of the leaf, following the veins, and the diseased tissues take on a characteristic purple color, so the conspicuous symptom of the malady is a purple striping of the leaves. The primary lesions usually appear on the older leaves, but, as the disease progresses, the younger leaves become involved and the bacteria may eventually penetrate to the center of the spindle, causing top-rot and the destruction of the affected shoot. The virulence of this disease depends, to a large extent, upon weather conditions. There is, therefore, little hope of arriving at a practical control of the malady by any means other than the use of resistant varieties.

New Disease in H 463

In February, 1923, our attention was called to a new disease which appeared in the seedling cane H 463 on Grove Farm Plantation. Dr. Kunkel visited Kauai to investigate this malady and his report on the subject reads as follows:

> The disease was found to be present in a one-acre plot of this cane growing in Field 34. The same variety growing at a low elevation in Field 3 was found to be healthy. The most conspicuous symptoms of the disease are a yellowing or dying of tops and a shriveling of the affected stalks. When diseased stalks are split open, discolored red areas and streaks are seen in the inner tissues. The disease first attacks the stalk a short distance above the surface of the soil. From the point of attack, it spreads in both directions and kills the stalk. In some cases, all of the stalks in a stool were affected, while in other instances only one or a few of them showed the disease. The affected cane was about one year old.
>
> The disease seems to be a new one and is due to the attack of a fungus parasite. The cells of the discolored stalk tissues are filled with a coarse septate mycelium. The fungus has been isolated and is now growing in pure culture. It has not yet been determined.

Additional material of diseased H 463 was brought to the Station during March by Mr. Pratt and from this we again isolated the fungus which appears to be the cause of the malady.

At a later date, healthy canes of the varieties Lahaina, H 109, Badila and H 146 were inoculated with this fungus, but in no case did it produce a lesion resembling those found in the diseased sticks of H 463.

We are inclined to believe that this fungus is but a weak parasite and that it was able to attack H 463 only after the vitality of this cane was reduced by some other factor. The only alternative is to conclude that H 463 has a weak constitution.

Sectional Chlorosis

This name has been applied by Mr. Naquin, of Honokaa, to a curious banding of the cane leaves which appears simultaneously on the shoots over considerable areas. Three or four consecutive leaves are always affected and the injury appears as a white band across the leaf, the band being 1 to 4 inches in width. The tissue within the band is nearly or quite white, having lost a part or all of its green coloring matter. It is quite evident that these bands are due to an injury suffered by the leaves while they are rolled up in the spindle, the tissues injured on the different leaves being superimposed at the time the injury is inflicted. When the leaves later unroll, the injury on the outer leaf will be near its base, while the injury on the innermost leaf will be near its apex, the other two leaves being injured at points intermediate between these two extremes. As the injury becomes apparent only after the leaves unroll, no one has seen the cane at the exact time when the injury takes place. Apparently the cause operates for a short time only and simultaneously on all of the canes in one neighborhood; for injured shoots show but one series of bands, and the position of the bands on all of the shoots in any one area occupies relatively the same position on the affected shoots, indicating that all shoots were injured simultaneously. In some cases, the tissues in the bands are so seriously affected that they die and the portion of the leaf above is consequently rendered useless. In the majority of cases, however, the banded leaves function normally in all portions except those within the bands.

Sectional chlorosis has been noted in fields at very low and at moderately high elevations and on both irrigated and unirrigated canes. As yet, we are unable to offer any satisfactory explanation for the phenomenon.

Deterioration in Yellow Caledonia.

Some apprehension has been caused along the Hamakua coast of Hawaii by the appearance in sticks of Yellow Caledonia of symptoms suggesting a serious internal disorder. Outwardly, the sticks appear to be healthy, but when split open the greater part of the tissue in the center of each internode shows a white, pithy appearance. In some of the more advanced cases, the central tissue has turned brown in places and fissures of considerable size may be present.

These symptoms are not of uncommon occurrence in overripe Caledonia cane. They are not due to any parasitic organism, but canes showing these symptoms are rapidly approaching a condition where they will fall easy prey to the ever-present rind disease fungus.

The cells occupying the central region of an internode in a well grown stick of Caledonia are often deficient in cell sap and the pipe of lighter tissue so often seen is due to the presence of air in cells which should be filled with juice. As the cane ripens, or suffers for lack of water, the juice may disappear entirely from the central tissues of the internode which then become quite white and pithy. As the cell walls dry up, they may turn brown and often break through shrinkage.

Forestry

(From a report by H. L. Lyon)

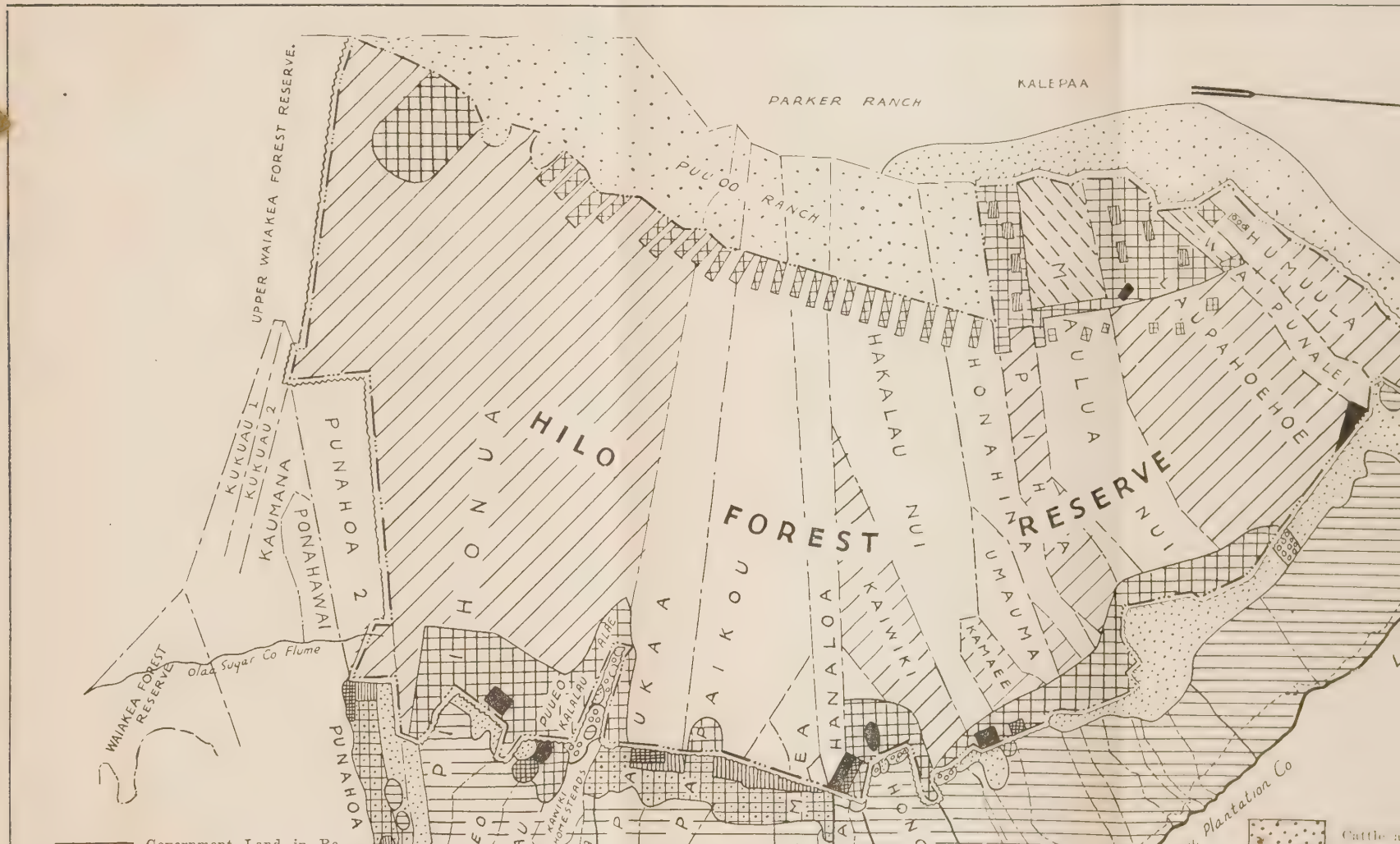
Hawaii

For the sake of economy and efficiency in forestry work on Hawaii, we have entered into a cooperative agreement with the Board of Commissioners of Agriculture and Forestry whereby the services of Mr. L. W. Bryan are divided between that Board and this Experiment Station. This arrangement is proving very satisfactory to all concerned. It has reduced overhead expenses, eliminated all duplication of effort and insures much better returns for moneys expended.

Attached hereto is a status map of the Hilo Forest Reserve, prepared by Mr. Bryan. This map tells, graphically, the present condition of this Reserve, what has already been done to protect and improve it, and what remains to be done to put it in proper shape. It also illustrates how any forest reserve should be treated to make it a forest reserve in fact as well as in name; and shows how every forest reserve in these Islands should be handled.

HILO FOREST RESERVE

Status Map 1923
Map and Survey by E. W. Hockley
Hawaii Territory Survey
Status by L. W. Bryan
Experiment Station H. S. P. A.
Dept. of Botany & Forestry



Among the notable improvements made in the Hilo Reserve during the past year, we might mention the completion of sixteen miles of boundary fence and the planting of over 90,000 trees. Mr. Bryan estimates that the area within this Reserve which must be reforested totals some 20,000 acres.

Work in the Halawa-Niulii Reserve has been well systematized. Two men are permanently employed and live in a camp within the Reserve. They patrol the fences, repairing all breaks, drive out any stock gaining entrance to the Reserve, plant trees and keep the grass away from the young trees until they are of sufficient size to shift for themselves. During the past year, these men have planted out some 7,500 trees in addition to taking care of the 65,000 previously planted.

Mr. F. W. Woods has taken a most commendable and effective step in his plan to improve forest conditions on the Kohala Mountains. He has fenced off and set aside as a forest reserve some 2,546 acres in the lands of Kehena. This new Reserve lies in a most strategic position, for it extends from the mauka boundary of the Halawa-Niulii Reserve to Puu Pili on the very crest of the Kohala ridge. Unfortunately, most of the native forest in this new Reserve is dead.

There are now four contiguous forest reserves on the Kohala mountains, containing a total area of some 50,000 acres. The forest cover in the Halawa-Niulii Reserve (area 2,842 acres) is being adequately protected and constantly improved. The Hawaiian Irrigation Company, the Honokaa Sugar Company, and Pacific Sugar Mill are planting trees on a small scale on the lands under their control, but aside from the work thus being done in two small areas at the extreme ends of these reserves, no systematic attempt is being made to strengthen the forest cover on the Kohala Mountains. This forest cover is conspicuously poor and quite evidently growing poorer from year to year. It has been entirely replaced by Hilo grass over large tracts. Planting operations should be started at critical points within these reserves and maintained on a scale sufficient to counterbalance the deterioration now going steadily on.

Oahu

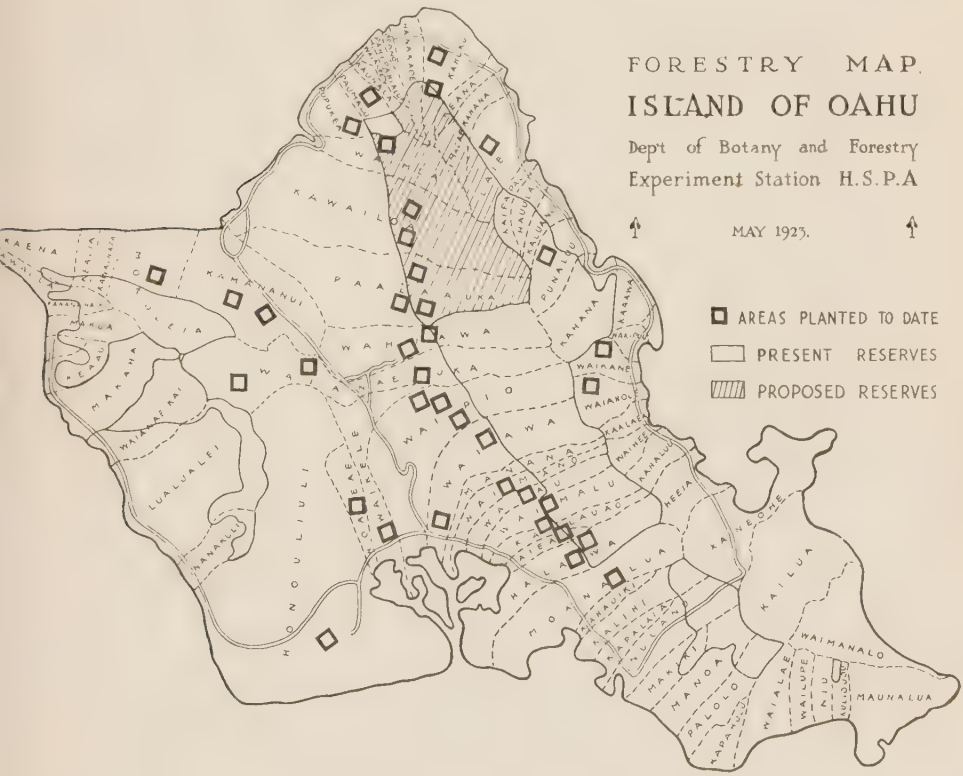
A careful reconnaissance has been made of the watersheds on Oahu and a fair idea obtained of the condition and extent of the native forests and the size and location of areas which should be planted.

Experimental plantings, including a great many species of trees, have been made at intervals from Moanalua to Kahuku on the Koolau Range and at several points on the Waianae Range.

These have given us valuable data regarding the most suitable trees to plant.

Seeds of the Moreton Bay fig have been sown by hand on stumps and logs in the forest. Many sturdy seedlings have sprung up and established themselves as a result, thoroughly demonstrating the efficacy of this method of reforestation in partially denuded areas.

In cooperation with the officers of the Board of Commissioners of Agriculture and Forestry, we are endeavoring to organize a forest reserve that will include all of the effective water-conserving area on the Koolau Mountains. The watershed to be protected by this forest reserve is the most important one on these Islands and its condition is such as to make it the one most in need of attention. The old native trees have been dying off rapidly and no new trees have sprung up to take their places. This process has been going on for many years until the formerly dense rain-forest has deteriorated into a semi-open forest, into which the uluhi fern has penetrated deeply, reaching the very crest of the main ridge at many points.



The accompanying map showing the status of our forestry work on Oahu was prepared by Mr. McEldowney.

Maui and Kauai

No cooperative forestry projects have yet been organized on Maui or Kauai under the supervision of this department. Extensive plantings have been made on both islands, however, by plantations working independently, the young trees for these plantings being supplied from our Vineyard Street Nursery.

Nurseries

Under the constant and able supervision of Mr. Forbes, work at the Vineyard Street Nursery has been thoroughly systematized and the efficiency of the nursery greatly increased. There is now on hand at this nursery a capacity stock of excellent material for distribution during the coming winter. During the period covered by this report, 194,850 seedling trees were shipped from this nursery.

With the assistance and cooperation of the Bureau of Agriculture and Forestry, the Wahiawa Water Company and the citizens of Wahiawa, we have secured the free use of some five acres of government land in Wahiawa for a forest nursery. The Wahiawa Water Company has laid a pipe line to this nursery and supplies us with free water. Mr. McEldowney is rapidly creating here a very efficient nursery in which we expect to grow a large number of trees for distribution on Oahu. We are also propagating at this nursery for distribution to other islands highland trees which do not thrive, even as seedlings, in the low land nurseries in Honolulu and Hilo.

As a result of our arrangement with the Board of Commissioners of Agriculture and Forestry, Mr. Bryan has taken charge of the Government Forest Nursery at Waiakea. We are confident that, under his direction, the capacity of this nursery will be at least doubled, thus greatly increasing the number of trees available for planting on the island of Hawaii.

The Makapala Nursery, established as a part of the Halawa-Niulii project, is only operated on a scale sufficient to supply material for the two men permanently employed on the project. This nursery is conveniently located and, with a little additional equipment, could turn out a large number of trees for planting in the two reserves which directly adjoin the Halawa-Niulii Reserve, if arrangements could be made to extend our plantings to these reserves.

We are experiencing considerable difficulty in rearing, at our lowland nurseries, trees of suitable species for planting at high

elevations. We have reached a stage in our work in the Hilo Reserve where we wish to make extensive plantings on areas between 4,000 and 7,000 feet elevation. To supply proper material for these plantings, we have completed plans for the establishment of a nursery in the land of Honohina at about 5,000 feet elevation. While this nursery is intended primarily to supply the Hilo Reserve with trees, its establishment is a most essential step in our forestry research, for we must determine by actual experiment what trees can be used advantageously on our mauka lands. This nursery in Honohina will provide us with the facilities for starting upland trees in a region where unlimited space is available for experimental plantings.

Arboretums

The Manoa Arboretum is proving to be a most essential trial ground for introduced trees. It provides us with a garden in which rare trees obtained in limited numbers only can be systematically placed so that their location and identity can be made a matter of record.

We expect to derive much valuable information from the several arboretums which have been established at various elevations on Oahu, Maui and Hawaii. Mr. McEldowney has made several plantings on Oahu which are worthy of being designated arboretums. They are conveniently placed and so arranged and charted as to make it possible to keep track of the trees planted. Mr. Bryan has planted several arboretums at various elevations in the Hilo Reserve and on the Kohala Mountains. These are all accurately charted, and, in addition, each group of trees of one species is marked with a metal tag bearing the name of the tree. The Wailuku Sugar Company has devoted a large field, formerly in cane, to the creation of an arboretum. Many species of trees have already been planted in this garden and there is still room for many more. The Honolua Ranch has also started an arboretum to which we are contributing.

The importance of these several arboretums as sources of information on the habits and requirements of the trees which we are introducing cannot be overestimated. In a few years they will also be supplying us with seed for use in the further distribution of the desirable species.

Sugar Technology

(From a report by W. L. McCleery)

Annual Synopsis of Mill Data

The 1922 Synopsis published as Circular No. 39 contained data from the forty-one factories belonging to the Association. Eight factories had not finished grinding when the Synopsis was compiled, but the unharvested portion amounted to approximately only 2.5 per cent of the total 1922 crop.

Weekly Mill Reports

A total of thirty-four reports has been published to September 15. One more will be issued before the end of the fiscal year. Two of these reports were published in 1922 and thirty-two during 1923. Mill reports have been regularly received from thirty-eight Hawaiian factories, and from the Hawaiian-Philippine Company. Waimea and Waimanalo did not send reports.

Commercial Sugar Reports

There have been sixteen reports and three summaries published. One more summary will be issued shortly.

Sugar samples have been received regularly from thirty-seven factories, and one factory has sent in samples occasionally. The samples examined to September 10 represent 450,000 tons of sugar.

Sugar from twenty-seven factories, representing 71 per cent of the total number reporting, averaged above standard, and the sugar manufactured above standard amounted to 82.4 per cent. The latter figure is the highest percentage yet obtained for any season. In 1922, there were no figures available, though the work was undoubtedly poorer than for several years. In 1921, 55 per cent of the factories were above standard, and the sugar above amounted to 67.5 per cent. The 1920 figures were 60 and 75 per cent respectively.

There has been considerable improvement in reducing the amount of dark seed grain. A total of 88 per cent of the sugar was free from any dark seed. In 1921 this figure was 74 per cent and in 1920, 78 per cent. The amount of conglomerate grain is hard to judge, but as near as we can tell there appears to be fewer conglomerates than in previous years.

Factory Inspections

The following inspections have been made:

By W. R. McAllep:

Koloa Sugar Company
Lihue Plantation Company, Ltd.
Kekaha Sugar Company, Ltd.
Kilauea Sugar Plantation Company (1st)
Waimea Sugar Mill Company
Makee Sugar Company
McBryde Sugar Company, Ltd.
Hawaiian Sugar Company
Olowalu Company (2nd)
Maui Agricultural Company, Ltd.
Hawaiian Commercial & Sugar Company
Oahu Sugar Company, Ltd.

By W. L. McCleery:

Kilauea Sugar Plantation Company (Oct., 1922)
Ewa Plantation Company
Waimanalo Sugar Company (2)
Waianae Company
Pioneer Mill Company, Ltd.
Kaeleku Sugar Company, Ltd.
Olowalu Company (1st)
Olaa Sugar Company, Ltd.
Waiakea Mill Company
Hutchinson Sugar Plantation Company (1st)
Laupahoehoe Sugar Company
Kaiwiki Sugar Company, Ltd.
Hamakua Mill Company
Honokaa Sugar Company
Hawi Mill & Plantation Company, Ltd.
Union Mill Company
Halawa Plantation, Ltd.
Kohala Sugar Company
Niulii Mill & Plantation

It was noticed this year that there was increased attention paid to high extraction stimulated by the higher price of sugar. The milling plants have been kept cleaner than before, as it is becoming recognized that sour cush-cush accumulations cause expensive sucrose losses.

Clarification is continuing to receive more attention, and an increased amount of lime is being used in the majority of factories as a result of our investigations and recommendations.

Practically no extra fuel is being used for sugar making purposes other than a part of the molasses in a few places. A number of factories are generating electric power for outside purposes with a large financial credit to the factory for the power furnished. Several factories have piled up large amounts of

bagasse adjoining the mills and one (Pioneer Mill Company) has a huge amount of bagasse on hand and at the same time has furnished several hundred horse power of electric current for use outside.

Increased attention is being paid to keeping the grain of the commercial sugar above standard, due, apparently, to resuming publication of the commercial sugar reports.

Low grade work is receiving more attention and a number of factories are showing decreased molasses purities, without increased low grade capacity, and as high or higher grinding rate. The tendency to hold a minimum of low grade massecuite in storage has been more pronounced than usual, due to the desire on the part of the management to produce as much sugar as possible before a decline in price.

The Filtering Qualities of Hawaiian Raw Sugars

(From a report by Walter E. Smith and W. L. McCleery)

The results of this investigation indicate that the difficulty in filtering solutions of Hawaiian raw sugars is due almost entirely to the presence of cane wax.

Early in the investigation a definite relationship was found to exist between the filtration rate and certain suspended material, which we called "Non-settling Matter." This material may be best defined by outlining the method used for its determination: The solution was first filtered through a fine linen cloth, thereby removing bagacillo and coarse material; the filtrate was then centrifuged for ten minutes in an oil-centrifuge; the supernatant liquid was siphoned off, and passed through an asbestos pad in a Gooch crucible; the residue was thoroughly washed, dried, weighed, and the weight recorded as "non-settling matter." The filtration rate was found to be inversely proportionate to the amount of non-settling matter, the relationship holding so constant that it was practically possible to calculate the filtration rate for any given sugar when the amount of non-settling matter contained was known.

Later it has been found that the so-called non-settling matter is principally, if not entirely, cane wax. Though this substance is only present to the extent of a few hundredths of a per cent, a difference of 0.05 per cent in the amount of wax contained will distinguish between sugars of excellent filtering qualities and the very poorest.

The presence of bagacillo, even in comparatively large amounts, has not been found to render filtration more difficult. On the contrary, the addition of ten times the normal amount

of bagacillo ordinarily found in raw sugars to refined sugars, carried at higher alkalinity than refinery practice, actually increased the filtration rate.

No evidence was found to indicate that difficulties in filtration were brought about by intensive milling. On the contrary, the factories producing sugar of excellent filtering qualities all attained high extractions, while the three factories which did not come up to the higher standards of extraction in every case produced sugars decidedly inferior from the standpoint of filtrability.

Investigation of the factors influencing filtrability suggests three principal lines of action for the improvement of the filtering qualities of Hawaiian raw sugars:

Increase of Polarization:

Our data show conclusively that for any given massecuite the filtration rate of the resulting sugar will be directly proportionate to the purity. This does not mean that any sugar of high polarization will necessarily have a high filtration rate, but under any given condition of manufacture the filtering qualities of the sugar can be improved by increasing the polarization; this is due to the fact that the cane wax is contained largely in the film of molasses surrounding the crystal.

In the boiling system practiced at Pioneer Mill, the so-called "A" sugar has better filtering qualities than "B" sugar of the same purity, which similarly filters better than "C" sugar of equal purity, a fact established in several tests made this summer. This suggests that perhaps a greater amount of wax can be eliminated with the molasses by this system of boiling than with the customary method, wherein only one grade of commercial sugar is made. The idea seems quite logical, but sufficient data have not yet been secured to permit a definite statement on this point.

That inboiling and return of non-sugars is not of itself responsible for poor filtering qualities of sugar may be seen in the fact that practically all of the mills producing the better filtering sugar practice the usual boiling system, while the method employed at Pioneer Mill does not of itself result in good filtering sugar.

The effect of using seed grain was studied in considerable detail and a number of strikes were boiled in experimental apparatus to determine the importance of this factor. In every test it was found that sugar from strikes grained on syrup had slightly better filtering qualities than sugar made from the same material using seed grains as the basis of the crystal. While the results definitely favored graining as opposed to the use of seed grain,

the difference was only slight and probably not sufficient to offset the advantages gained at the raw sugar factory by seeding as now practiced.

Improvement of Clarification and Disposal of Settlings:

In practical terms it might almost be said that the filtering qualities of raw sugar can be measured by the clearness of the clarified juice from which it is produced. The factories producing the sugars of high filtration rate are characterized by clear, brilliant juices after clarification; on the other hand, the factories producing sugar markedly inferior as to filtrability have turbid juices in every case studied.

Since the greater part of the cane wax is eliminated with the settlings, it is vitally important that no mud be allowed to contaminate the juice sent to the evaporators. Filter press mud contains from 12 to 15 per cent cane wax on dry substance, or from 4 to 5 per cent on weight of mud; a few pounds of press mud may therefore contain more wax than many tons of well clarified juice. Where filter press juice is returned to the clarified juice rather than to the raw limed juice, a leaky cloth may re-introduce sufficient wax to offset the advantages of excellent clarification. A similar situation exists where the first runnings from the settling tanks are not sent to non-settled juice or settlings.

In short, the most urgent improvement needed at the raw sugar factory is for better clarification, with clear, sparkling, mud-free juices as the end in view. This will no doubt require further study into the factors which affect clarification, using the word in its literal sense—*to make clear*—rather than from the standpoint of elimination of impurities.

A Possible Reduction of the Alkalinity of the Raw Sugar Solution Previous to Filtration at the Refinery:

It has been observed that the addition of lime to a raw sugar solution materially reduces the filtration rate. Marked differences have been found in filtration rates for the same sugar at reactions slightly alkaline to litmus and slightly alkaline to phenolphthalein. Since the conditions under which these tests were made duplicate the refinery conditions of filtration, it seems likely that improvement might be brought about by a reduction of the alkalinity of the raw sugar solutions at the refinery.

The results of our practical tests are also confirmed by the chemistry of cane wax and its reaction with lime. About 70 per cent of cane wax consists of stearin, olein, palmitin and other glycerides of the fatty acids; in solutions made alkaline with

lime these fats are saponified, producing insoluble calcium compounds of a particularly greasy nature, with the probable quality of being able to materially affect filtration. That this is actually the case was demonstrated by filtering a refined sugar solution to which 0.02 per cent of stearin had been added in the form of its ammonium compound with sufficient lime to produce a slight alkalinity to phenolphthalein. It was found that the filtration rate had been retarded 35 per cent.

This phase of the question will of necessity require further detailed study, preferably at the refinery, and the advantages in filtration carefully balanced against the disadvantages of the reduced alkalinity before a definite opinion can be formed. Should it prove practical to operate the refinery at a less alkaline reaction or should it be possible to add lime or other alkali after filtration, this method offers perhaps the greatest opportunity for immediate improvement in the filtrability situation.

Clarification Investigation

(From a report by H. A. Cook and W. L. McCleery)

Summary of an Investigation to Determine if Possible the Hydrogen-ion Concentration or Reaction at which Inversion Begins in Clarified Juices when held at High Temperatures

It was hoped that there might be found a definite point in hydrogen-ion concentration or in the reaction to litmus or phenolphthalein at which inversion would start in clarified juices.

The investigation was carried on by liming juices at different alkalinities for clarification, and keeping the juice at the desired temperature in an electric oven, the heat controlled by means of a thermostat. A study was made on juices at four different temperatures, namely: 180°, 190°, 200°, and 212° F.

Due to the lack of time in which to make a thorough study of the data found in this investigation, general conclusions only can be given. In the light of a complete study of the data these conclusions may be changed, modified or strengthened.

Conclusions:

There does not appear to be a definite hydrogen-ion concentration or reaction to indicators at which inversion starts in clarified juices.

It appears that the influence of the temperature at which the juices are held is the largest factor influencing the starting of inversion.

There is a decided difference in the reaction point and the rate of inversion between 180° and 212° F., as shown by the data. This is true of clarified juice as well as for pure sucrose for which the figures given by authorities are from 1,354 at 180° F., to 5,659 at 212° F., or over four times as great.

It appears that the higher the juice is limed for clarification, the lower the hydrogen-ion concentration may drop before inversion begins.

It does not appear that the amount of glucose originally present influences inversion.

It does not appear that the concentration of sucrose present in the juice influences the point at which inversion begins.

Phenolphthalein as an indicator does not give any indication as to the point at which inversion starts.

A few points on each of the four temperatures follow:

(212° F.):

The hydrogen-ion concentration at which inversion starts varies from a pH of 6.07 to 7.34, although there are strong indications that a pH of 7.0 is the danger point.

At this temperature it would seem that inversion would start positively at a reaction of .005 alkaline to litmus as indicator. In no case did juices held at this temperature, even when limed high enough that the clarified juice showed decidedly alkaline to phenolphthalein or a pH of nearly 9.0, hold up for twenty-two hours, and in nearly all cases inversion had started in from two to four hours.

In one series, limed so that the clarified juice showed just slightly alkaline to litmus (.002), inversion had started in less than two hours.

(200° F.):

At this temperature the results are very similar to those found at 212° F., although inversion is not shown quite as positively at the same reaction point.

(190° F.):

At this temperature inversion starts at lower pH value than at the above two temperatures, although there does not appear to be a definite point at which it does start.

Litmus as indicator does not seem to give any indication, for in some cases inversion starts while the juice is alkaline to litmus and in others not till an acid condition has been reached.

Juices limed alkaline to phenolphthalein, cold, do not show inversion in twenty-two hours.

(180° F.):

Juices held at this temperature are directly comparable in the experimental data with those held at 212° F. and show decided differences in the inversion points.

180° F. is decidedly the best temperature at which to hold juices for keeping, provided the liming has been carried to the proper point.

As a comparison with 212° F., the juice which was limed to faintly alkaline to litmus on the clarified juice, at this temperature kept perfectly for four hours and even then the signs of inversion are only slight, not showing to any extent till after six hours. At 212° this juice showed decided inversion in two hours. The pH had reached 4.63 in six hours at 212°, while at 180° it was 5.65. The litmus reaction had reached neutrality in six hours at 212°, while at 180° it was still neutral to litmus at the end of twenty-two hours.

A juice limed to about half way between litmus and phenolphthalein neutrality showed no inversion in twenty-two hours. The litmus reaction had dropped to slightly alkaline in twenty-two hours, while the pH had reached 5.65.

While no definite hydrogen-ion concentration or reaction to indicators can be given at which inversion will begin, it appears that the liming during clarification should be carried to a point high enough so that the juice will remain plainly alkaline to litmus during the time the juice is kept at a high temperature.

The initial point at which the liming should be carried will depend upon the temperature at which the juice is maintained, and the time the juice is maintained at that temperature.

In order to keep juices for any length of time the cold juice should be limed alkaline to phenolphthalein in the liming tanks, and the temperature then maintained at 180° F.

A Study of the Rate of Change of Reaction of Clarified Juices when Maintained at High Temperatures:

An investigation has been completed to determine, if possible, the rate of change of reaction of cane juices clarified at different alkalinities and held over a period of time at 180°, 190°, 200°, and 212° F.

This investigation was carried out to give as much practical information as possible. It was not attempted to go into the question from a purely scientific basis as the means and apparatus were not available. It was desired to secure information that would be of value in actual milling practice. The determination of sucrose or purities was not made. The reactions alone were studied in these experiments.

The reactions were studied in regard to litmus and phenolphthalein as indicators, and the hydrogen-ion concentration as determined by use of the hydrogen electrode.

It was intended to study the rate of change of reaction up to the point where it was expected that the inversion of sucrose might begin. Previous work along another line had given an indication of this point. The reaction determinations were made every two hours for the four temperatures, except at 212° and a few at 200° F. At 212° and most reactions at 200° F., the above point was reached in six hours.

It was found that while carrying the juice from the acid or raw state to an alkaline or clarified juice by the use of lime, there was a direct relationship existing between the reactions to litmus, phenolphthalein and hydrogen-ion concentration, but that when the juice began to change to an acid reaction this relationship no longer existed. This has been accounted for to some extent but not altogether.

At 212° F., there is a very rapid change in the reaction during the first two to four hours. The change is more abrupt during the first two hours, after which the rate gradually becomes slower. At the end of four hours all the reactions studied were below the neutral point in hydrogen-ion concentration, and in six hours all but the highest initial point (.001 acid to phenolphthalein, pH 8.73) below the theoretical neutral point to litmus, although by actual titration most of the series were above this point.

Previous and later work show that at this temperature, inversion will start above the neutral point to litmus or at a pH of around 7.0.

At 200° F. the results secured were very similar to those at 212° F., showing the same abrupt drop in reaction during the first few hours.

At 190° and 180° F. the results were very similar although somewhat slower at 180 than at 190. Both of these temperatures differ decidedly from the two higher ones. The drop in reaction during the first two or three hours is much less abrupt. The results at 180° are perceptibly slower than those at 190. At both of these temperatures the reaction at the end of twenty-two hours is much more alkaline than at the two higher temperatures.

At 180° F., an initial reaction of a little over 8.20 pH drops to only 7.60 in six hours, and the one just slightly acid to phenolphthalein (pH 8.80) remains above 8.0 for six hours.

To illustrate, the difference in the rate of change at the last mentioned pH, i.e. 8.80, the following points in six hours are reached at the four different temperatures: at 180° it drops to

8.05, 190° to 7.60, at 200° it drops to 6.90, and at 212° it drops to 6.60. This pH is at the point at which Bomonti has shown in his work on clarification that the largest increase in purity is obtained and at which point he also secured the best results in clarification. This pH had dropped to only slightly below 7.0, pH in twenty-two hours and from all indications it is very doubtful if any detectable inversion had started at this temperature. None of the juices studied at this temperature dropped below the neutral point to litmus.

To illustrate in another manner the difference in the rate of change in reaction at the different temperatures, the hydrogen-ion concentration was calculated in a manner so that whole numbers were secured which were given the term "times increase in ionization." In this manner it was shown that the "times increase in ionization" was as great in five hours at 212° F. as in twenty-two hours at 180°, with the same initial alkalinity.

By this method of calculating is shown the effect of varying the initial alkalinity and maintaining the same temperature. For example, at 200° F., with an initial pH of between 8.5 and 9.0, the increase in ionization is over 260. As compared with an initial pH of between 8.0 and 8.5 it is only 190. Illustrating the same point, an initial pH of between 8.5 and 9.0 at 180°, the increase in ionization is a little over 80 compared with over 200 at a temperature of 190°, and compared with an initial alkalinity of between 8.0 and 8.5, the increase is about one-half as great at the lower alkalinity.

It can be stated that the influence of heat is greatest in the early stages of the process, and is the more marked in the juices of the higher alkalinity or pH value. However, it is also shown that for a given temperature, a high alkalinity will remain alkaline for a longer time than will a lower alkalinity.

The Effect of the Use of Sodium Carbonate and Sodium Bi-Carbonate with Lime in Clarification:

An investigation is being conducted to determine the effect of sodium carbonate and sodium bi-carbonate used together with lime in the clarification of cane juices.

It is desired to show the effect of their use in regard to the following points: effect on clarification, on purity, the color of the clarified juice; on the amount of ash in the clarified juice, and their effect on the removal of lime salts from juice.

The experimental work on this investigation has not yet been completed and will require a few more weeks provided mill juice can still be obtained.

In the absence of complete data from which to draw conclusions, only the following general observations can be made. There seems to be no beneficial effect derived as to the settling qualities or the clearness of the juice. When the liming is carried to the point where the maximum increase in purity is obtained, there is no further increase in purity but rather a decrease, due to the addition of sodium carbonate and sodium bi-carbonate. In some cases where the maximum increase is not obtained by use of lime, there seems to be a small increase with small amounts of both sodium carbonate and sodium bi-carbonate, the purity decreasing, however, upon the addition of larger amounts. There seems to be a small progressive darkening in the color of the juice upon the addition of increasing amounts of both carbonates, though the darkening is not quite as great with the use of the bi-carbonate. There appears to be an increase in the percentage of ash, due to the addition of both carbonates, increasing with an increase in the amount added. The increase is not as large with the use of the bi-carbonate. There is a removal of lime salts which, however, does not approach the theoretical capacity of either carbonate. The sodium carbonate seems to be the more effective.

The Accuracy of Determining the Hydrogen-ion Concentration of Cane Juices by the Use of the Hydrogen Electrode:

The question has been raised as to the validity or accuracy of the determination of the pH value of cane juice by the use of the hydrogen electrode, especially as the clarified juice changes from an alkaline reaction to an acid reaction.

Several determinations have been made on this point and it is desired to make several more by the use of specially prepared standard buffer solutions and appropriate indicators. This is the method as proposed and used by Clark and Lubs.

The determinations already made indicate that the method now in use, the hydrogen electrode, is accurate for this measurement.

The reason for this investigation, which should take very little additional time, is the large divergence in the results obtained by titration with the use of phenolphthalein and litmus as indicators.

Miscellaneous

Molasses Investigation:

The only work that has been done this year has been the reboiling of two samples of molasses. A sample of Olaa molasses

was reduced to a gravity purity of 27.56. The details have already been reported.

A sample of Pioneer molasses was reboiled in our apparatus and the resulting molasses was 26.6 gravity purity. The details of this test will be reported shortly.

The molasses resulting from the experiment on last mill juice at Oahu Sugar Company was reduced in our experimental apparatus to 28.66 gravity purity after allowing for suspended solids. The details of this will be reported later.

Calibration of Instruments:

The calibration of brix hydrometers, flasks, etc., the standardizing of weights, and the overhauling, adjusting and repairing of polariscopes and accessories has been continued. Eight polariscopes and one refractometer were given a thorough cleaning, etc., this being a larger number than during any previous season. This year the necessary tools and equipment needed for working on polariscopes while visiting the plantations on factory inspections have been carried with our other apparatus, and at least ten additional polariscopes have been given more or less complete overhauling.

Methods of Analysis:

Further work has been done in collaboration with the Methods Committee of the Association of Hawaiian Sugar Technologists on the revision of the Methods of Analysis and Control.

Soil Investigations and Allied Projects

(From a report by G. R. Stewart)

Research Work

Our work on soils has made substantial progress during the past year. I have noted in past reports that our soil investigations have been divided with two major lines of activity. One of these is the study of the composition of the principal soil types included in the plantation fields, and the other has consisted of more fundamental investigations in the problems of soil fertility. In recent years there has been a great difference of opinion upon the mainland of the United States as to the value of any chemical determinations made upon field soils.

The work of various investigators has shown that great variations exist in the composition of different portions of the same field. Work upon plant adaptation has shown the large influence exerted by all the outside factors which affect plant growth, such as the depth of the soil, the texture, the exposure of the land, the temperature, the rainfall and the elevation. Probably each one of these factors is as important as the actual chemical composition in the effect exerted upon plant growth.

It must be recognized, however, that the soils of the mainland of the United States represent a greater diversity of origin, and have a far more extensive geological history, than the volcanic soils of the Hawaiian Islands. The crops grown in most mainland agricultural regions cover a comparatively wide range when contrasted with the problems of the sugar industry here, which are concerned with only one standard crop.

Certain general facts concerning fertilizer practice in the islands have been developed by agricultural experimentation. Practically all our soils respond to nitrogenous fertilizers. Certain soils, notably in the Hilo district, respond also to potash applications. Certain upper fields in other districts give a fairly general response to phosphate fertilizers as well as to nitrogen. It appeared to us to be worth while to try and find what outstanding differences there were in those soils which did or did not respond to potash and phosphate applications. This work has been completed by Mr. McGeorge during the past year and I shall summarize it later on, in this report. I only wish to state my conclusion here. I believe his results, taken together with our work on samples collected by us from plantation fields, tend to show that analytical work on our cane land is of value, especially when followed by field experiments to test the deductions from the analyses. Only broad general deductions can be made from such analyses; and they must be interpreted in the light of all possible information upon the other factors of environment which affect plant growth so largely. Fundamental studies must also be carried on which are designed to give us further information as to the way the sugar cane plant grows and assimilates its essential elements. A combination of these two lines of work, one dealing with practical field studies and the other with plant nutrition, appears to me ideal for an institution such as ours.

Special consideration has been given duirng the year to the soils of the following plantations:

Koloa Sugar Company,
Knudsen Bros.,
Ewa Plantation Company,
Oahu Sugar Company, Ltd.

This work has been handled partly by Mr. Hansson. These soil surveys should be helpful, for they have a very direct bearing upon fertilizer policies and the location of field experiments.

Effects of Fertilizing Salts on Hawaiian Soils

This work is a continuation of the laboratory and lysimeter studies mentioned in the last Annual Report and discussed in an article in the Planters' Record, Vol. XXVI, page 186. Since completing the above laboratory experiments, we have carried out two series of field experiments in which nitrate of soda was applied to three typical soils at Ewa plantation. All applications were made at the rate of 100 pounds of nitrogen or 650 pounds of nitrate of soda per acre. These applications were first made to young ratoons and plant cane in August, 1922. The fields were sampled before fertilization and were later sampled periodically after the fertilizer was applied. We found the nitrate nitrogen was largely retained in the top two feet of soil. Some penetrated into the third foot, but very little went down into the fourth foot. In several cases the irrigating water passed down into the fourth foot of soil to an appreciable amount, without taking down a corresponding percentage of nitrate nitrogen with it. This clearly showed that there was an even better retention of nitrates in the undisturbed field soil than we found in our lysimeters. We found that the first season's application of nitrogen was absorbed out of the soil by the plant, in about ten weeks or less.

The second season application of nitrate of soda was also followed by means of periodic samplings. This nitrate dressing was taken up more slowly, but was largely withdrawn in about three months after it had been applied.

With some soils there appeared to be a slight increase in alkalinity, following applications of nitrate of soda. Under field conditions this gradually tended to disappear.

The Tolerance of H 109 Cane for Heavy Applications of Nitrate of Soda and Ammonium Sulfate

When we attempt to apply the necessary fertilizer which is required to raise maximum cane crops under the most favorable conditions, it is often asked: How much nitrogenous fertilizer can be put in cane without injuring it? In order to answer this inquiry, an experiment was started in October, 1922, using H 109 cane. In this experiment uniform stools, grown from single eye cuttings, were started in small seed boxes, and then transferred to large concrete pots, two feet square and two feet deep.

All treatments were made in duplicate. Two pots were left untreated as a control, with no fertilizer. Nitrate of soda was applied to one series of duplicates in amounts ranging from 25 pounds of nitrogen per acre from nitrate of soda, up to 200 pounds of nitrogen per acre. To another series, ammonium sulfate was applied in amounts ranging from 50 pounds of nitrogen per acre. The first application of fertilizer was made at the end of October, approximately one month after planting. Since this time the same applications of nitrate of soda and ammonium sulfate have been made each month. This now makes a total of eleven applications. The cane receiving the heaviest treatment of nitrogen, in both forms, has at times, just after an application of nitrogen, appeared to be slightly hurt. All the stools are still strong and healthy, however.

The drainage water has been collected from all the treatments and analyzed for the different forms of nitrogen. Only traces of nitrogen in the form of ammonia and nitrites have been leached out. Moderate amounts of nitrogen in the form of nitrates have been lost. The largest losses do not amount to more than 10 to 20 per cent of the amounts added. Evidently the soil or the crop has retained most of the excessive nitrogen applications which have been made. The experiment shows that there is little danger of injuring the growth of cane plants by any application of nitrate of soda, or ammonium sulfate, which is likely to be made under field conditions.

A Study of the Phosphates in the Island Sugar Soils

Mr. McGeorge has completed the above important investigation during the past year and the results will shortly appear as a Station bulletin. I gave a summary of the principal deductions which could be drawn from the analytical data which had been collected at the time our last Annual Report was prepared. The completion of this work did not cause any of these deductions to be changed.

In its final form the bulletin consists of an analytical examination of all the principal plantation soils upon which the Station has carried out phosphate experiments. There is also a summary in the second half of the bulletin of the results of the field experiments with phosphates which the Agricultural Department has carried out on the four principal islands of the group. This material was collected by Mr. McGeorge with the cooperation of the agriculturists of the Station.

The entire publication is a valuable contribution to our knowledge of the sugar cane soils of these islands. It has been espe-

cially important to have such a summary of the composition of the soils from the experimental areas, together with the conclusions which may safely be drawn from the field results. This work promises to be of great use in our examination of plantation soils and should aid in choosing areas for phosphate experiments.

The Availability of Potash in Hawaiian Soils

This study has been completed by Mr. McGeorge during the past year. It covers the soils of the potash experiments in somewhat the same way that the previous investigation took up the areas where phosphate trials had been carried out. These two pieces of work, taken together, make a valuable contribution to our knowledge of the Island soils.

Mr. McGeorge summarizes his results as follows: "It is evident from a review of the field experiments of the sugar lands of the Islands that the majority of soils do not respond to potash fertilization. The principal factor which appears to be related to the availability of this form of plant food is the presence or absence of lime. Also, there is some indication of the greater availability of potash in the clay types. The solubility of silica appears to be without effect upon the availability of potash."

In making recommendations or suggestions as to fertilizer practices, considerable value may be attached to the analysis of the soil where the relation of citric soluble potash, shown in this paper, is used as a basic guide. Knowing the demand which sugar cane makes upon the soil potash, with additional consideration of our knowledge of the properties of Island soil types, the following rule may serve as a general guide for future experimentation: A plantation soil showing 0.02 per cent K_2O soluble in 1 per cent citric acid will with rare exceptions respond to potash applications regardless of the lime content of the soil. Those soils within the range of 0.02 to 0.03 per cent may be considered as deficient in available potash and will usually show a slight response, especially where lime is low. Finally, with few exceptions, soils containing more than 0.03 per cent K_2O soluble in 1 per cent citric acid will rarely give profitable returns from potash applications.

The above is suggested not as an infallible rule, but rather as a guide to fertilization, developed from the analyses of soil samples collected from lands on which a knowledge of potash availability has been determined by field experiments. No attempt is even made to apply this to Island soils generally, but only to those cropped to sugar cane. The more conservative policy would be to use the soil analyses as a guide to the placement of individual plantation field experiments.

The Carbon Content of Plantation Soils

Mr. McGeorge has made a valuable study of the organic matter in a considerable number of representative plantation soils. Recent investigations have shown that the determination of the organic carbon in a soil is the most reliable indication of the amount of total organic matter present in it.

Using this method of investigation, Mr. McGeorge found that our soils are amply supplied with organic matter. The highest organic content was found in the soils of the humid districts. The red soils of the dry sections of the Islands were the lowest. The differences in organic matter were more nearly related to the early growth of wild vegetation on the soil than to the present productivity of the land.

On the basis of data obtained from the analysis of a set of comparative soil samples from the cultivated and uncultivated portions of nine fields at Ewa plantation, there was no indication that the present cropping system is depleting the organic matter of our plantation soils.

Study of Changes in Available Plant Food

A preliminary review of the results so far obtained in this investigation was given in last year's Annual Report. This piece of work followed the changes in the different forms of soluble nutrients found in two sets of experimental plots, one being Experiment 6, Field 45, Oahu Sugar Company; the other, Experiment V, Waipio substation. We made periodical samplings of the soil in both fields and completed this work after the Waipio experiment was harvested this spring. The results are now being prepared for publication.

Our completed work agrees with the preliminary report in showing the early absorption of the more important nutrients. It also shows that a 1 per cent citric acid solution is the most satisfactory solvent to determine the availability of the important nutrients in our Island soils. We have obtained needed information from the study upon the changes which take place in available plant food during the growth of a crop. These results, taken along with Mr. McGeorge's work on phosphates and potash, enable us to interpret our work on plantation soils with a better understanding of probable fertilizer response.

Root-Rot Investigation

We have recently commenced work on what we plan to make an extensive investigation of the chemical factors which influence the development of root-rot. We group under this term such

troubles as Lahaina disease and similar root diseases which affect other varieties of cane. Several investigators who are working on the root diseases of corn at the Indiana Experiment Station, have recently shown that root-rot of corn is at least partly caused by the poisonous effect of soluble iron and aluminum in the soil This condition also results in a disturbance of the normal nutrition of the plant, so that it is decidedly starved for phosphates and potash.

We plan to have Mr. McGeorge devote his entire time to this problem for the next year or more. Other members of the Chemical staff will also work on some parts of the investigation.

Mr. McGeorge has outlined the following preliminary plan of work:

1. *Nutrient Studies.*

(a) Root stimulants and root toxins. Under this heading would be included a study, beginning with water or sand cultures, using the compounds which have been recognized in previous investigations on root development, and such additional substances as may be suggested by a knowledge of local soil conditions. Under the above would be included experiments with aluminum and iron salts and wide variations in soil reaction.

(b) It is essential that we include studies in the effect of variation in the plant food balance upon root development. Our preliminary tests have shown an almost complete absence of root growth when nitrates are entirely lacking, even though the plant may be amply supplied with ammonium salts. In such tests nitrate-forming bacteria were carefully excluded so no nitrification could take place. This would also include a careful trial of the theory developed at Indiana, that a lack of nutritive balance, such as a shortage of phosphates and potash, contributed to the disease.

(c) An attempt will be made to determine the effect on cane development and root growth of more careful and frequent early irrigation, together with the early application of both fertilizers and non-plant food stimulants.

2. *Root Respiration.*

Soil investigations have shown that the air content of the soil is a primary, controlling factor in root development. The composition of the soil air varies with the nature of the soil, the time of year, seasonal changes, cultivation, plant growth, etc.

We know that aeration is sluggish in Hawaiian soils. We also know that studies of the lime requirements of plants have

indicated that sugar cane is a strong lime feeder, and as such it should produce a strong excretion of carbon dioxide. The general effect of this would be a reduced oxygen supply, an accumulation of excretory products and a reduction of respiratory activities. Field studies have shown the basic importance of oxygen to root activity and the injury wrought by the accumulation of carbon dioxide in the soil atmosphere. A study of cane root respiration therefore appears highly essential in order to clear up these points.

(3) *Soil Oxidation.*

This subject is closely related to that of aeration. It has been found at Rothamsted that the same factors that influence fertility also influence the rate of oxidation in the soil. This process is greater in fertile than in non-fertile soils, in surface soil than in subsoil. This portion of the investigation would include a study of the oxidizing power of our soils and the influence of various field practices upon this soil function.

We plan to carry on the above work in close cooperation with the departure of pathology and obtain the benefit of their training in studies of the various tissue changes associated with the differences in growth, which we may encounter. We have already started two joint field experiments at Ewa Plantation, which we have laid out with the department of pathology. In these experiments, Lahaina cane has been used and a variety of heavy phosphate applications have been made to try and find whether toxic aluminum salts were a factor in producing root-rot in the Ewa fields.

Further Observations of Backward Ratoons on Kauai

It will be remembered that there was considerable comment during the harvesting season of 1922, on the poor development of Yellow Caledonia ratoons on the island of Kauai. Many Caledonia ratoon fields suffered seriously from root-rot. It was thought that part of this root-rot trouble might be due to punctures in the roots caused by minute insect or animal life. Mr. Swezey made a special study of the soil inhabitants that could attack the roots of cane, and further work has been done on this subject by Mr. Pemberton. Their work has shown that small snails and centipedes may be responsible for some, at least, of these root punctures.

In our observations on Kauai last year, Mr. Swezey and I found some root injuries in almost all the cane fields we examined. Some of the best and most vigorous ratoon fields had as

many root injuries as the weakly ratoons. We found in general that the backward ratoon fields were most prevalent in the cooler districts and were largely confined to the Yellow Caledonia variety of cane.

In late July of 1922, I made a second visit to Kauai and found that at this season, during the warmest weather, the Caledonia ratoons were starting vigorously, even in the upper fields. Areas cut during this warm period were in many cases further advanced than the same ratoon crops on adjoining land which had been cut in the coolest months of the year. There was even more indication from these observations that the trouble was partly due to an unfavorable season, and partly to some decrease in the vitality of the Yellow Caledonia variety of cane.

Mr. Swezey and I have again visited all the plantations on the island of Kauai during early May, 1923. The past winter had been decidedly more favorable for the growth of cane crops. We found a few fields where the ratoons were starting slowly, but in all cases these were in the coolest sections. The plantations are also meeting the problem by doing more frequent replanting. This is possible, on the upper land, by means of planting machines which have been developed by Messrs. Broadbent, Larsen and Moler. More vigorous ratooning varieties are also being tried where Yellow Caledonia has proven unsuccessful. Among these varieties, Yellow Tip and Striped Tip are making an excellent growth, but no harvesting results are yet available.

We again found some punctures on nearly all the roots examined. These punctures were also found on the roots of cane growing in the warmer districts of the island, where the ratoons of Yellow Caledonia always develop vigorously.

Investigation of the Use of Water at Waimanalo

We are conducting an investigation into the use and value of irrigation water at Waimanalo in cooperation with the plantation management. This work was undertaken at the request of Messrs. C. Brewer & Company. The fields of Waimanalo Sugar Company, which embrace some 2,700 acres of cane land, have always been very short of water. Recently, additional water has been developed, on adjacent leased land, but the supply is still considerably below the standard applications of the better irrigated plantations. In connection with future plans for water development, it became important to know how much growth was being made under present conditions, compared to what could be obtained if an adequate water supply were available.

We accordingly started a series of comparative growth and moisture studies on various typical fields of the plantation. In

this work we laid off an area in three fields which was to receive complete irrigation in contrast to similar adjacent lands which received regular plantation treatment. Two of these extra irrigated areas were started with cane which was ten to twelve months of age. The third was young plant cane which was just coming up. In addition to these three irrigation experiments we also laid out several plots to measure growth, soil moisture and irrigation water in representative fields which received ordinary plantation treatment. This work was started by members of the Station staff, but is now being carried on at Waimanalo by Mr. William Weinrich, who is employed by the Waimanalo Sugar Company. We still cooperate by making the moisture determinations and assisting in the observations on the growth of the cane.

The observations were started the last of June and the present summary of data applies up to the first of September. Measurements of the water applied, showed that the usual irrigation was about 94,000 gallons or 3.59 acre inches of water per acre. The frequency of irrigation which will be required to keep the soil up to the optimum moisture content for good growth, we find, will vary with the retentiveness of the soil and the slope of the field. In the more level fields, which have good water-holding capacity, we find an interval of two weeks between irrigation is about ideal for large cane. On fields which have a greater slope, or where the soil is more open, about a week is the proper interval between irrigations.

Our measurements of the growth of the cane under varying conditions of irrigation showed an absolute agreement between the frequency of irrigation and the rate of growth.

One field of H 109 plant cane had received sufficient water to be in fair growing condition at the time we started our studies. With full irrigation the stalks of cane in this field have made an additional growth of four and a half to five feet. This is contrasted with three feet of growth for the ordinary crop cane. A second field of H 109 plant cane was not making such vigorous growth when we started our observations. Here the response to complete irrigation has been four feet of average growth, contrasted to 2.4 feet in the crop cane.

Probably the most striking difference has been obtained with the young plant cane. Here the fully irrigated area has made a growth of 1.55 feet, while the ordinary treatment has grown only 0.26 feet. The development of new sticks on young cane with full irrigation has amounted to about 100 per cent increase. With a shortage of water there has been only 39 per cent increase in the number of sticks per line.

At the present time the growing temperatures at Waimanalo are excellent. The maximum temperatures have been slightly over 85° F., with minimum temperatures of 70° to 72°, making an average mean temperature of 78° to 79° during the past two months. This is an excellent range for good cane growth.

It is planned to continue this work during the cooler months of the year. We shall measure whatever growth the cane makes after there is plenty of moisture from rain, even though the temperature has decreased.

Cooperative Field Experiments

(From a Report by J. A. Verret)

This branch of work is now much better provided for than has been the case heretofore. Mr. Pratt is devoting all his time to extension work, while Mr. Paris devotes a part of his time to outside visits. Both of these men are well qualified for this work and I look forward to very satisfactory progress.

I believe that in this work our main efforts during the next few years should be devoted to seedlings and bud selection. The fertilizer needs of the different districts have been fairly well covered. On the other hand, it is becoming more apparent every day that we need better canes—canes which will be better adapted to the varying conditions in the different districts. This applies particularly to large parts of Kauai and to Kohala and parts of Hamakua. The seedling and bud selection work will be covered in more detail in other sections of this report.

In the matter of field experiments, we have discontinued a fairly large number in the districts which have been fairly well covered in other years. On the other hand, a few plantations and the Kohala district have not been so well covered. So we have put in a number of new experiments in Kohala and on Koloa and at Pioneer. These new experiments about equal in number the ones dropped on other places, leaving our total number of field experiments about the same. These field experiments are distributed as follows:

Crop Year	Hawaii	Kauai	Maui	Oahu	Total
1924	23	29	6	11	69
1925	16	14	16	9	55
Total	39	43	22	20	124

The above tabulation is subject to change. A number of the experiments may have served their purpose before harvest and be discontinued, or new experiments may be put in for the 1925 crop.

We harvested forty-six 1923 crop experiments. We have one left to be taken off.

Summary of Experimental Results for the 1923 Crop

Varieties:

The Tip canes are giving favorable results on the higher elevations on Kauai and are being spread. Throughout Hawaii they also continue to be used for the higher elevations. Yellow Tip is favored. In regard to these canes, we desire to again call attention to their main weakness. The Tip canes are rather freely susceptible to mosaic and when attacked are badly damaged. It is therefore extremely important that great care be taken in the selection of seed. No diseased seed should ever be planted. It would also be well not to plant Tip canes adjacent to corn fields or grass pastures as corn and a number of the grasses harbor the corn aphis.

In a carefully conducted experiment at Grove Farm, H 472 and H 456 gave better yields than Yellow Caledonia out of a total of nine canes tested. The experiment is being repeated on the first ratoons.

In a small test at Onomea, conducted by the plantation, H 456 gave very gratifying returns.

In a test at Honokaa, carried through three crops, D 1135 produced 50 per cent more sugar than either H 109 or Badila and double the yield of Yellow Caledonia. At the end of the third crop the D 1135 was still ratooning well, while the others averaged less than ten tons of cane per acre.

At Pioneer Mill, D 1135, Striped Mexican, H 33, H 109, H 146 and Lahaina were compared for two crops. D 1135 led in yield in both crops, while Striped Mexican was second in average. The field was at an elevation of about 500 feet and did not have optimum water.

At Maui Agricultural Company a comparison was made between H 109, D 1135, Rose Bamboo, Striped Mexican, H 146 and Lahaina. The test was carried through two crops. H 109 was first, D 1135 second, and Rose Bamboo and Striped Mexican third.

Liming:

A liming test at Hilo Sugar Company was harvested, testing the residual effect of the lime. On the previous crop, lime had been used at the rate of from 1 to 6 tons per acre. From this liming an average gain of about 2 tons of cane per crop per acre was obtained.

Forms of Nitrogen:

In tests at Waipio and at Maui Agricultural Company, ammonium nitrate did not seem to give as good results as the same amount of nitrogen from nitrate of soda. This was especially the case at Maui Agricultural Company. We are unable to account for this difference. As in previous years, nitrogen from quickly soluble salts continues to give better returns than equal amounts from organic materials.

Amounts of Nitrogen:

The results of our nitrogen experiments are along the lines previously reported. Depending upon conditions, profitable limits in nitrogen fertilization vary from about 130 to 300 pounds per acre. It is not possible or advisable to attempt to establish an average of general application to all plantations. The proper procedure must be worked out for each place. On the plantations where soil, climatic and water conditions are poor, the limit is about 150 pounds of nitrogen per acre.

Cane uses about 3.5 to 4 pounds of nitrogen per ton, and when thin soil, dry weather or cold winters limit the production to 20 or 30 tons of cane per acre, we see no advantage in using more nitrogen than the cane can use or will use. But it is extremely important to apply this nitrogen when the cane can make the most use of it. On the other hand, under good conditions two to three hundred pounds of nitrogen per acre can be used to advantage.

Methods of Applications:

Experimental returns continue to show no advantage in applying fertilizer in numerous small doses. When one practices early fertilization to cane only a few weeks old, it seems best not to make this first dose too large, as the root system does not yet penetrate deep enough to take full advantage of the soluble nitrogen. At Waipio we believe we get good results by making the first dose to plant about 50 pounds of nitrogen and to ratoons about 80. Later applications range from 100 to 155 pounds each.

Phosphoric Acid and Potash:

Potash continues to give large returns along the Hilo coast. Profitable returns were gotten from amounts as large as 400 pounds of sulphate or potash per acre. As one proceeds from the Hilo district into Hamakua and Kohala there is a much less need of potash indicated. Most Kohala soils are high in potash. Tests at Honokaa show no returns from either potash or phosphoric acid.

Makee soils showed some response to potash, but not to phosphoric acid. At Lihue there was no appreciable response to potash or phosphoric acid on medium elevations; mauka lands respond to phosphoric acid.

In five complete fertilizer experiments at Wailuku there were slight gains from the phosphoric acid and potash in four. Pioneer responded to phosphoric acid, while potash needs are doubtful.

Maui Agricultural Company showed no response to either.

Green Manuring:

Plowing under of crop of lupines in a test at Hamakua Mill showed no increase over check plots fallowed without lupines. The test is being continued for another crop to determine the effect, if any, on the ratoons.

Width of Row:

In a test at Kilauea, 3-, 4- and 5-foot rows gave yields of 21.2 17.2 and 16.8 tons of cane respectively per acre, the increased yields from narrowing rows about corresponding to the increased amount of seed needed to plant them. So it would seem that the width of row to use at Kilauea should depend on cultivation economics rather than cane yields.

Cultivation:

A series of tests carried out through several crops on the island of Hawaii show no increased yields from off-barring, plowing or hilling. In fact the yields may actually be lowered. In the practical application of these results the proper procedure would seem to be the cheapest means of weed control with the least disturbance of the root system of the cane. In this connection it is well to know that in ratoons the young shoots feed to quite an extent through the living roots of the old stumps until they develop a system of their own. This has a bearing on off-barring. Off-barring by cutting off old living roots limits the feeding of the new shoots by just that much.

Sugar Cane Varieties

Hawaiian Seedlings

(From a report by J. S. B. Pratt, Jr.)

Double the number of seedlings were set into the field this year as in any other year. The final count on a few of the seedling areas is not in, but the total estimate for this year, as actually set out in the field, is 80.254, distributed as follows:

Kohala district	23,000	
Manoa	40,000	
Honolulu Plantation Co.	4,054	
Oahu Sugar Company	10,000	(est.)
Waipio	200	
Makiki	3,000	
	80,254	

Under Experiment Station auspices, there have been raised to the present time, some 190,605 seedlings by years, as follows:

1904	280	
1905 to 1911	5,116	
1911	336	
1912	25	
1913	3,684	
1914	1,275	
1915	4,720	
1916	613	
1917	18,466	
1918	10,154	
1919	21,670	
1920	42,042	
1921	278	
1922	1,692	
1923	80,254	(est.)
	190,605 *	

This year's total, then, of 80,254 seedlings is 42 per cent of the total raised to date.

Figuring 4,000 plants per acre, this year's seedlings cover twenty acres of individual seedlings.

* This total does not mean "total germinations," for there is a selection of a large number from the flats by nature, and possibly 20 per cent of this year's seedlings that were potted, and which looked weak, were thrown out. The total means those actually put in the field for preliminary trial. This total also does not include the seedlings raised by plantations such as Ewa, Honokaa, Hilo Sugar Company and Honomu in previous years.

Parentage of Seedlings:

The majority of the seedlings raised this year at Kohala by Mr. Jennings (a total of 23,000) were seedlings of Striped or Yellow Tip crossed with D 1135.

In 1917, at Kohala Sugar Company, from 277 seedlings of D 1135, five at the present time, K 73, K 107, K 115, K 117 and K 202 are excellent ratooners on third ratoons, and are proving to be commercial canes for the district. They all have Tip characters in growth, eye, size, ability to close in and to ratoon, and everything points definitely to the male parent as being a Tip. Getting 5 out of 277 is an excellent percentage, and shows what our chances are in working with this cross as a mauka or "cheap production" cane. We have an excellent lot of material to watch in the next few years.

On looking over the most desirable seedlings at the present time, it is very striking to note the large number of good seedlings from Lahaina, and H 109, with Striped Mexican next as a good parent. It would seem from a study of the parents of those showing up, that Lahaina and H 109 crosses with some Striped Mexican are the most desirable parents to work with for makai land canes. For mauka lands, the D 1135 by Tip crosses would seem to give the best chances, and as second choice, crosses from Uba and Badila.

Uba Hybrid No. 1:

This year, Mr. Kutsunai and Dr. Kunkel, by cross pollination, succeeded in obtaining and raising five Uba hybrids by D 1135. Uba Hybrid No. 1 is a heavy stooler and a fast grower. It shows many of the desirable Uba characters, with a stick as large as D 1135. We would be exceedingly lucky to obtain a commercial cane from five seedlings, but Uba hybrids start off so well that other similar crosses will be gone after this year to the extent of all tassels that can be obtained. Uba Hybrid No. 1 will be used as a parent when tassels are obtained; a seedling from this would contain 25 per cent of Uba blood.

Promising Seedlings for Makai Lands:

While not proven on large field tests, nor the ratooning ability definitely decided, we would place the following as the most desirable canes for the makai lands, taking them up by propagations:

(a) *Early propagations.* None except H 109.

(b) *The "H 400" Series.* H 456 is perhaps the most promising cane so far to take the place of Yellow Caledonia for the

Hilo district. It shows that it will ratoon well at Onomea, indicating that it needs moisture. H 468, H 471 and H 472 are being carried on yet.

(c) *The* 1915 *Series—H* 109 *lot.* H 5922 and H 5965 to date the best of this series. Waialua has the largest amount of these.

(d) *The* 1917 *Series—Oahu Propagation.* Three of these are of exceptional promise. No. 229, now called Honokaa No. 1 (a Striped Mexican seedling); No. 347, now Ewa 800 (a Lahaina seedling); No. 394, now 801 (an H 109 seedling). Ewa 800 is an excellent ratooner, a yellow cane much resembling Lahaina.

(e) *The* 1917 *Maui Propagation or Wailuku Seedlings.* Sixty-three of these have Wailuku numbers. Perhaps Wailuku Nos. 2, 4, 6, 9, 10, 13 and 50 are showing up favorably upon more plantations than the others. Six plantations on Kauai, two on Hawaii, four on Oahu, and five on Maui have these canes. Seed is being grown at Makiki and Waipio for further distribution. Wailuku No. 2 and No. 9 are making a good showing at Onomea.

(f) *The* 1918—*H* 109 *Seedlings.* We would place about fifteen of these as canes worth carrying on further: H 8958, H 8978, H 8961, H 8965, H 8994, H 89102, H 8949 (subject to eye-spot), H 8988, H 8906, H 8982, H 8969, H 8984, H 8948, H 8992 and H 8942. During the year, we have distributed them to practically all the plantations, and the next cutting of our seed patches will complete the list. In two tests in Makiki, H 8994, H 89102 and H 8988 had better juices than H 109 grown under the same conditions.

(g) *The Ewa Seedlings.* Seed was obtained from Ewa, and we have started distributing their most desirable ones. Ewa 177, Ewa 720 and Ewa 509 are perhaps the best. Now that two seedlings of our 1917 Series—Oahu Propagation have been given Ewa numbers, Ewa 800 and Ewa 801 are most desirable.

Seedlings for Mauka Lands:

(a) *Kohala Seedlings.* Discussed previously in this report, K 73, K 107, K 115, K 117 and K 202 are the most promising. Honokaa favors K 220 for its conditions. All these seedlings are from D 1135 tassels and show strong Tip characters. This cross, D 1135 x Tip, is giving good units and will be carried on extensively.

(b) *Manoa Seedlings.* Quite a number (about 2,000) of Tip crosses were set out in Manoa this year. Of the 1922 propagation, some 200 Tip seedlings were sent out to four plantations without waiting for a further selection here. These will

be carefully watched. They represent 30 per cent of the field test 1.

(c) *Uba Seedlings.* Uba Hybrid No. 1 is the type desired for mauka land, and though not proven out, it indicates the desirability of such crosses.

(d) *Badila Seedlings.* We have only a few at present, but Badila, D 1135 and Tip crosses are desired. The difficulty is in getting Badila tassels at the same time as the other varieties.

Seedlings Distributed During the Year:

We are installing a "Kardex" system to keep better records of the seedlings sent out to the plantations. Cards of one color will contain records of the varieties on the plantations, cards of another color will be lists of seedlings that should be sent to plantations as soon as seed is available.

The 1918 Series—H 109 seedlings were sent to nearly all plantations during the year. The next cutting of our seed patches will have all plantations trying these.

The Wailuku seedlings are fairly well distributed. By next planting season all plantations will have the better ones.

The same applies to the Ewa seedlings.

We will be able at the same time to establish the Kohala seedlings on the mauka lands of the plantations needing this type of cane.

The Manoa Tip seedlings were cut and sent to four plantations for trial, two on Kauai and two on Hawaii.

Seedling Work on the Islands:

The seedling work may be considered the big project of the year.

Mr. Jennings in Kohala placed into the field some 23,000 seedlings largely of Tip crosses. Close observations were made of the Kohala seedlings of the 1917 propagation.

On Maui, work was confined to the material on hand. Messrs. Broadbent and Stender harvested a large number of seedlings of the 1917 and 1920 propagations.

No new seedlings were raised on Kauai. We have a vast amount of material already there; also with the better material sent from the other islands. Mr. Markwell, with Mr. Poole, of McBryde and Makaweli, harvested the seedlings there, and they have spent a large part of their time on seedlings. The Koloa seedlings were planted out by Mr. Markwell.

On Oahu, some 55,000 seedlings were raised by Mr. Kutsunai. Also, material was secured from Wailuku, Ewa, Kohala, etc., for the raising of seed for later distribution.

Future Work:

The work for the coming year will consist to a great extent in "following up" the seedlings already at hand. When a particular seedling shows promise, we will secure seed and anticipate a future demand for it, and those places having it will be notified. This is a most valuable part of the extension work.

It is planned to concentrate the raising of new seedlings to Makiki, where large numbers can be raised cheaply. A very rigid selection will be made when placed into the field, and then only 15 to 20 per cent of these will be sent out to certain plantations for further trial. In this way a large number of the poorer seedlings will be eliminated, and plantation areas can be held more to a higher standard than the field tests 1 usually show.

A most interesting experiment this year at Makiki indicates that this policy is sound. On setting the plants in the field a rigid selection was made. The weak plants were placed in checker-board plots, the strong ones in the others. There is hardly one seedling in the poor plots that will be worth carrying on. These may show better on the ratoons, but the chances of securing the best seedlings are so much greater when large numbers are handled and a most rigid selection made. The "world beater" may be lost by such a policy, but the chances can be figured out mathematically showing the value of working with numbers and being rigid. One manager expresses it: "Drown your kittens while they are small, else you may have so many you can't handle them." When a seedling shows a defect, discard it and let its place be taken by a more promising one.

We quote from the "Record" of April, 1923, page 111: "Out of the many thousand seedlings raised in Queensland, only a few were finally selected. In Barbados, over one million seedlings were raised, yet only four are in general use. The same story holds at Demerara, possibly seven canes out of a million." We have raised to date, in the Islands, only about 200,000 (actually put in the field). We were exceedingly lucky to obtain H 109 out of 5,000 seedlings. We would venture the statement that we have several seedlings of H 109's equal at the present time.

There can be raised very cheaply large numbers of seedlings at Makiki. These can have a most rigid selection (poor types can easily be picked), then the small amount of material from the one stool can be divided into four equal parts and tried out under four sets of conditions.

This was done with the 1917 seedlings. Already Honokaa has fourteen acres of one of these, now called Honokaa No. 1, which we have observed as very poor at Pioneer, but good at Olaa. It probably would not have been selected under Makiki

conditions. It was tried under at least six different conditions. Two others, now Ewa 800 and 801, are equal to H 109 at present. Pioneer had these and upon being notified of Ewa's findings, reports that they are also good there. We have sent the Manoa Tip seedlings out with the same idea, and they will be carefully watched under the different conditions. The varieties to be used as parent canes have already been discussed in this report.

We report a stimulating interest in seedlings on the majority of the plantations.

Resistance to Disease and Adverse Conditions by Hardy Sugar Cane Types

(By H. P. Agee)

The recent epidemic of mosaic disease in Porto Rico, aggravated as it was by root disease, has brought to the fore in several sugar countries a type of cane which heretofore has been overlooked or neglected.

With the collapse of standard Porto Rican varieties through the ravages of mosaic and root-rot, it was found that immunity to these maladies was possessed by certain thin-stick, hardy canes of North Indian origin.

In discussing root disease in 1920, F. S. Earle*, of Porto Rico, listed a great many varieties, denoting their relative resistance to root-rot. He gave four varieties which he said were practically immune to root disease:

Kavangire	P. O. J. 105
P. O. J. 36	P. O. J. 234

Kavangire is a cane that was brought to Porto Rico from the Argentine, where it had been imported from Brazil. It is very similar to, and probably identical with, the Uba of Natal, a variety which has superceded all other canes under the prevailing adverse conditions of that country. Uba is occasionally written "Yuba" or "Yuban," and the variety is sometimes confused with Zwinga, which is said to be very similar, but an inferior type. Zwinga is listed by Earle as a Japanese fodder cane.

We have been unable to get a positive identification of the cane that goes by the name of "Uba" in Hawaii. It was formerly called "Japanese cane" both here and in Louisiana, from which

* Journal Dept. of Agriculture of Porto Rico, Vol. IV, p. 3.

state it was probably brought to these islands. There is, however, no difference between Uba and Zwinga with regard to immunity to mosaic and root disease. They belong to the Ganna group of North Indian varieties.*

In P. O. J. 36, 105 and 234 we again find the characteristics of the hardy North Indian canes exhibited in the disease resistance of these seedlings, for the work of Kobus, as a cane breeder, stands out through his early appreciation of the possibilities of introducing disease resistance into seedlings by crossing the hardy North Indian canes with the standard varieties of Java. Principally, he used Chunnee and Cheribon (the latter known locally as Rose Bamboo and in Cuba as Crystalina). P. O. J. 36, 105 and 234 are progenies of this cross.

The growing interest in hardy disease-resistant types is shown first by the record of Uba in Natal, where all competing varieties have been replaced; next, by the commercial plantings in Porto Rico of Kavangire as a relief from mosaic and root disease. Again, the Experiment Station in Cuba finds this type of great promise for Cuban conditions and reports having distributed cuttings of the Uba of Natal throughout the cane growing districts of Cuba. F. X. Williams, of this Station, writes from Jamaica: "Uba cane is coming into favor here, as it is a hard-boiled variety that chokes out all weed growth, Para grass being one of the worst, and it is said to be the only cane that will grow on very bad soils. It is not planted on good soils. It ratoons well. In one place this cane yielded twenty long tons to the acre on bad soil, on the ninth or tenth year; no cultivation after the first crop. Ratoons are usually harvested in about one year."

Dr. Calvino, of the Cuban Station, is working to produce what he terms a "Super-Uba." Having discovered that the Uba flowers are female fertile and male sterile, they made crosses using Uba tassels and pollen from Crystalina. Following this lead, Dr. Kunkel and Mr. Kutsunai, of this Station, have crossed our so-called Uba with D 1135, obtaining five hybrids, one of which shows interesting possibilities from a few months' growth.

There are definite indications that much of the world's sugar supply of the future is to be produced from hardy canes growing with a minimum of care. Under adverse conditions, efficiency in agriculture resolves itself ultimately into producing the greatest tonnage of sugar per man-day of labor. It is here that vigorous-rooted, weed-suppressing, strong-ratooning cane varieties

* See "An Annotated List of Sugar Cane Varieties," Journal Dept. of Agriculture of Porto Rico, Vol. IV, p. 3.

come into play in reducing the cost of production per acre to a very low value.

It is probable that Uba, in so far as it enters the field, will be used only as a temporary expedient pending the arrival of the hybrids that combine the hardiness and disease resistance of the North Indian types with the better sugar-producing qualities of the standard larger stick varieties that have produced most of the world's cane sugar of the past.

In some quarters we find such a program already in effect. In the Argentine, where Java canes were introduced about twelve years ago, the declining industry of Tucuman has been completely rehabilitated by the varieties P. O. J. 36 and P. O. J. 213. These have replaced the older varieties and are today the two commercial canes of Tucuman, each of them occupying areas of about 100,000 acres.

In Formosa, P. O. J. 36 has been rapidly extended to an area of 56,000 acres, replacing Rose Bamboo, which was formerly the most satisfactory cane of that island.

In Egypt, P. O. J. 105 has become a commercial cane.

Following the condemnation of the shipment of cane sent from Fiji in 1906, the Hawaiian sugar interests have had little concern about important foreign varieties. However, this matter came up for our consideration during the past year. On learning that the United States Department of Agriculture was furnishing Java canes to Louisiana and Porto Rico, we wrote to Washington and learned that these canes would also be available to us. About simultaneously the Territorial Board of Agriculture and Forestry was discussing quarantine regulations to restrict sugar cane introductions. The department heads of this Experiment Station had held a conference in February, 1922, and gone on record to the effect that they were prepared to endorse the introduction of reasonable quantities of valuable foreign canes, provided due precaution was taken with regard to the selection of the material in foreign countries and, provided further, that adequate quarantine facilities could be established before releasing such canes. The desirability of quarantining these canes first on the mainland and then here was considered an ideal way of meeting the situation. In January, 1923, Dr. E. W. Brandes, a plant pathologist of the U. S. Department of Agriculture, who had been working on the control of root-rot and yellow stripe disease in Louisiana and Porto Rico, passed through Honolulu en route to the Orient in search of hardy cane varieties. From him we received first-hand information of the quarantine houses at Arlington, Virginia, near Washington, which then housed important Java varieties.

Following a detailed consideration of the matter, the Association in February of this year addressed the Territorial Board of Agriculture and Forestry two letters, one endorsing a quarantine ruling whereby canes would be admitted under special circumstances, the other asking for a permit to introduce the cane varieties P. O. J. 36 and P. O. J. 213. It was understood that these canes would be first inspected in quarantine in Washington by Dr. Kunkel and Mr. Muir, of this Station. This permit was afterward extended, upon Dr. Kunkel's recommendation, to include P. O. J. 234 and P. O. J. 979.

These canes were shipped from Washington by Dr. Kunkel and reached here in May. Upon arrival, they were examined and passed by Mr. Muir and Dr. Lyon, representing the Station, and by Mr. Ehrhorn and Mr. Whitney, representing the Board of Agriculture and Forestry. The plants from which these cuttings were taken were grown from cuttings sent from Java with a certificate from the Dutch pathologists that they were free from sereh and yellow stripe disease. A quarantine of a year or more in Washington had developed no unforeseen dangers. An examination in Honolulu gave further evidence that these cuttings were free from potential danger to the industry, but as an additional factor of safety, according to the terms of the permit, they were planted in a quarantine house at the pathology plot on Alexander Street, which had been specially constructed to receive them. This house is designed to embrace the precautionary measures that our specialists in entomology and plant pathology have recommended. These imported canes are to be grown in quarantine under close observation for at least one year. If all goes well, cuttings will be released for planting in the open late in 1924. These Java canes, which will in all probability be available to Hawaii plantations in another year, are described as follows from information obtained from Dr. W. E. Cross, of the Tucuman Experiment Station:

P. O. J. 36. A relatively stout cane, erect in growth, which grows very thick in the row. Shows considerable resistance to mosaic and root disease. Very quick to germinate when planted or after cutting. Resistant to frost and drought. Deteriorates very rapidly after cutting and therefore must be milled within two or three days at most. The highest in fiber of the group under consideration, and also very hard; produced many mill breakages here until the people got used to it. Fairly early maturing, though later than the P. O. J. 234 and 213. Owing to its hardness, very resistant to borer, which has ceased to be a problem in Tucuman after the adoption of this cane. Is planted in Tucuman at 1.80 or 2 meters distance between rows. Constitutes about

half the total plantings in this province, having an extension of about 40,000 hectares. Averages in Tucuman about fifty metric tons per hectare. Color varies from green to a light pink. Gives excellent results as ratoons up to six or seven years stubble.

P. O. J. 213. Of equal importance in Tucuman as the P. O. J. 36, occupying practically the same extension of plantings. Thinner than the P. O. J. 36, a pronounced purple in color, has a reclining tendency, especially after winds or heavy rains. Grows even thicker in the row than 36. Not so quick to start when planted or after cutting, but after it attains a height of two feet grows very rapidly. Equally resistant to mosaic and root disease as 36, and more resistant to top-rot, from which I forgot to mention the 36 suffers to some small extent as plant cane. Resistant to frost and drought. Deteriorates after cutting about same as 36. Much softer and less fibrous than 36, and for this reason much preferred by the people in the sugar house. Earlier maturing than the 36, but not so early as the 234. Less resistant to borer than the 36. Production in Tucuman about same as 36, except that as plant cane, owing to later start, usually gives less. Ratoons even longer than the P. O. J. 36.

P. O. J. 234. Very rapid sprouting cane, always "up" before any of the others of this group, either as plant or stubble. Very early maturing, acquiring a high sucrose content and purity here after seven to eight months growth. Fiber content high, but not so high as 36. Always a very sweet cane, but does not produce much cane per acre (about like P. O. J. 228). Rather susceptible to top-rot when plant cane, and more susceptible than the others as stubble. Deteriorates more rapidly after cutting than any of the other varieties. Fairly resistant to mosaic and root diseases; also drought and frost, though in every case inferior in this respect to the 36 and 213. Formerly planted to considerable extent in Tucuman, to use in beginning of the harvest, but in last two years has lost favor. This is probably because it gave reduced yields as third and fourth years stubble, due to the fact that it had been cut early every year, for in subtropical countries the cane cut early in the winter gives a reduced yield in the following year, owing to the deterioration suffered by the stubble during the excessively long dormant period.

P. O. J. 979. This is one of the best of the Java seedlings being grown experimentally in Tucuman.

Dr. E. W. Brandes, on his recent trip to Java, Formosa and other points of the Orient, obtained and sent to Washington a number of valuable cane varieties, including some of the newer Java hybrids which show great resistance to root-rot and yellow stripe disease. He has furnished us a description of these varieties. The Chunnee and its hybrid progeny are not immune to mosaic. They acquire the disease but it does them little harm.

The Identification of Cane Varieties

(From a report by Twigg Smith)

The work of describing and classifying our cane varieties by means of the method used successfully in Java by Dr. J. Jeswiet has now been going on about five months, during which time I have been making drawings and examinations of most of our standard varieties, among which are Lahaina, Badila, Yellow Caledonia, Striped Mexican, D 1135, H 109, etc.; also many seedlings of H 109. Before quoting Dr. Jeswiet, it may be well to consider the present method of description based on appearance and why it is undependable. It is well known that color, shape of internode, growth habit, stooling and other easily distinguishable characteristics of cane are variable, due to agricultural or climatic conditions, and are therefore misleading and quite undependable, if used alone, for an accurate description of a variety.

Using only such a description it would be very easy for canes of similar appearance but different parentage to become mixed, with great accompanying losses. It is said that some progenies of H 109 and other of our canes are greatly alike in general appearance. Unless the greatest care is exercised, at some later date, those progenies may become mixed in with and classed as their parents with much resulting confusion, especially if used in crossing.

There is need, then, for a description that can be relied upon, especially with the strides being made in seedling and selection work.

Further, such a description or method of identification will give us an insight into the relation of the varieties and their origin, and will be of use in judging the seed consistency of the types obtained by repeated self-foundation.

In an article by Dr. J. Jeswiet (Java Archief XXIV, page 359) he commences the description of his method by defining the term *variety* or type as follows:

> From a pollinated tassel the seed is sown . . . theoretically it is possible to obtain the same individual but in practice it does not happen . . . Two entirely equal parts do not occur . . . some are selected on account of their superior qualities . . . one may be exceptional and later is cut up and multiplied through slips. Each cutting, each new plant is again part of the first individual originated vegetatively from the little seed . . . We learn from this that the cane variety is represented by an individual propagated in a vegetative

or non-sexual manner . . . The description of the variety then becomes the description of the individual . . . the description must be based on characters that are as constant as possible and little dependent on exterior influences . . . I believe these characteristics to have been found in the groups of hairs present on the outside bud scale, on the leaf sheath, ligular process, and leaf. These groups have proven to be sufficiently constant and can be used for the description of individuals from the type *Saccharum officinarum* as well as in the systematic system of the botanical types of the genus Saccharum.

Dr. Jeswiet made many experiments to establish the constancy of the system mentioned and found that it could be relied on if based on non-flowering stalks or plant cane from four to six months. With us, probably plant cane from six to eight months will be better. Non-flowering stalks can be distinguished only when cane is close to the flowering time.

I am now describing progenies of H 109; also Striped and Yellow Tip, making drawings of the eyes, ligular process, and leaf. Later these will be compared with the parent types of cane and separated into groups. Further familiarity with the method will enable me to determine individual parentage. Some canes are easily distinguished. For instance, it is easy to see in some of the Tip progenies a similarity to D 1135. Also, with a known cross of D 1135 and Uba, now six months old, it is plain that the crossing is correct, even though in general appearance no one of the seedlings are alike. At least we are sure that the seedlings have the cross in them that was wanted, which would be impossible at this early date, without such a description as Dr. Jeswiet's.

The method will be particularly useful in checking imported canes with a description of its growth habit and the Jeswiet characters from its mother country.

With our canes, where all the seedlings so far (with the exception of D 1135 x Uba) have been grown from seed gathered in the field, the problem of identification becomes a very complex one and it will not be possible to declare parentage without a very careful study. It does not mean that from any eye or bud taken from any stalk it will be possible to identify the variety, but from a reasonable amount of stalks it can certainly be done, and sometimes from just the one eye.

Improvement of Cane Varieties by Bud Selection

The Progress of Bud Selection Work

(From a report by A. D. Shamel)

The work of the project for the improvement of sugar cane through bud selection during 1923 has been largely devoted to (1) harvesting the progeny fields planted during 1922, (2) propagating the selected stools of the superior progenies in new progeny plantings, (3) the selection of apparently superior stools from plantation fields for additional progeny tests, (4) the selection of apparently disease-resistant stools for progeny tests of their inherent resistance to disease, and (5) an effort to further encourage plantation employees in observing and studying individual sugar cane plant behavior for the purpose of securing superior stools for propagation.

During the spring and summer seasons of 1922, experiment station and plantation employees selected a large number of apparently superior stools for progeny tests on most of the plantations in the Hawaiian Sugar Planters' Association. In these selections it was often impossible to determine whether or not the stools selected were developed from a single eye or from two or more eyes. Furthermore, in many cases the selected stools were often located at the ends of the rows or adjacent to vacant spaces in the rows where considerable uncertainty existed as to whether or not the size and development of the stalks in these stools were due to favorable environmental conditions or to inherently superior characteristics. The study of the behavior of the progenies from the selected stools during the 1923 season has thrown additional light upon the problem of selecting stools for progeny tests and emphasized the necessity for securing stools grown from a single eye, the individual sugar cane plant, for constructive improvement work. The experience of the present season has also suggested important changes in the methods of handling and planting the seed-pieces from the stalk of the selected stools and in the arrangement of the progeny plantings. The writer is of the opinion that great progress has been made in 1923 in developing improved methods of selection and propagation and that invaluable information has been obtained as a result of the experience in the harvesting and the systematic study of the progeny fields.

A detailed report is in progress of preparation showing the results of the bud selection work during the year 1923. This report will include the data secured from some of the progeny fields harvested during the present year together with a resumé of the experience and recommendations of the men doing the work. Owing to the fact that some of the progeny fields were not harvested until late in the season it has been impossible to get the data and observations in shape for publication in this report. It is believed, however, that these data can be prepared for publication before the work of the 1924 season begins so that everyone interested will have the opportunity of studying these observations and data in preparation for carrying on this work during the coming year.

In the harvest of the progeny fields this year the study and comparison of the progeny behavior has been greatly facilitated in several instances by stripping and topping the stalks shortly before cutting. Owing to the dense and oftentimes tangled conditions of growth it is difficult to study intelligently the stalk, stool and progeny conditions without stripping and topping. When stripped and topped it is a comparatively simple matter to walk along the rows and observe clearly the progeny behavior. In most fields certain progenies have stood out as unmistakeably better than the others and as evidently inherently superior. This superiority has been shown by the large number and size of stalks in the stools, which were uniformly above the average and by the fact that the stools in these progenies were all uniformly good. This condition indicates inherent stability for these characteristics which are correlated with high yields.

The stripping and topping should not be done too far in advance of cutting on account of the danger of injuriously affecting the power of germination or the vitality of the eyes and for other reasons. Unusually, it has been found practicable to strip and top the stalks of only those progenies to be harvested during the same day. After stripping and topping, a preliminary selection of stools, in the apparently superior progenies, can be made before the stalks are cut. A study of the stripped and topped standing stalks in the progeny field can hardly fail to be very instructive and valuable not only in interpreting the results of the progeny tests but also for training the eye for selection work as a whole. In a few cases where only top seed-pieces were used for propagation, the stripped and topped stalks were left standing several days before cutting for the purpose of securing larger eye development. Such seed-pieces have to be handled with great care in order to avoid damage to the enlarged eyes. In these instances the original color of the stalks was somewhat changed

due to exposure and due allowance had to be made for this condition in studying the stalk characteristics.

In cutting, the stalks of each stool were cut and laid down near the base of the stool, care being taken to keep the stalks of each stool separate from those of every other stool. The danger of misplacing and mixing the stalks of neighboring stools was further prevented by reversing the stalk position so that the tops of the stalks of one complete stool were laid opposite the butts of the stalks of the adjacent stool. When single-eye seed-pieces were not used, as was the case in most of the progeny fields, it was found advisable to inspect the stool arrangement before cutting so that the cutters would certainly keep the stalks of each stool separate. With experience, most cutters soon developed a keen sense of stool arrangement and made but few mistakes in separating the stools.

In weighing the stools, several types of spring balance and steelyards were successfully used. Where steelyards are commonly used in plantation practice, this apparatus gave satisfactory service and reliable weights. Where spring balances were used, they were found to be very compact and convenient for this purpose, but it was found advisable to check up their performance from time to time in order to determine their accuracy and reliability. As several individual stools were found which weighed about one hundred pounds, it was necessary to use balances arranged to weigh at least this amount.

The most convenient and accurate method for securing the stool weights was to tie the stalks of each stool into a bundle with cane-top tiers. During weighing, a rope or leather strap loop of suitable length was passed around each bundle in such a manner that it bound together and supported the bundle of stalks in a horizontal position. One end of the loop was passed over the hook on the balance after which, the bundle was raised free from all obstructions by two men, one at either end of a pole to which the balance was suspended. After recording the weight, the loop was detached from the balance, removed from the bundle of stalks and passed on for further use. Several loops were found necessary for each crew in order to carry on this work efficiently.

The length of each progeny in the row was determined either before or immediately after cutting. In practice this year, the length of the progeny was usually measured as soon as all of the stools were cut and weighed. A fifty-foot steel tape was found to be most convenient for this purpose, although, in a few fields, with very long progenies, a tape measuring one hundred feet was preferable. The measurement of each progeny was usually start-

ed from the middle of a normal space preceding the first stool and to the middle of a normal space beyond the last stool. Where stakes alone were used for separating the progenies, the measurements were usually from stake to stake.

The number of stalks in each stool was counted and recorded usually just after weighing. In most instances one of the men handling the balance counted the number of stalks while the weight of the stool was being recorded. If the stalks were so long that it was necessary to cut them into shorter pieces for convenient weighing, the counting of the number of stalks was usually done before the stalks were cut up in order to avoid mistakes in counting. Ordinarily, it was not necessary to cut up the stalks so that the counting was done immediately after the weighing.

The data upon which the selection of progenies and the selection of stools within the best progenies was based, included the length of the progeny, the weight of the stalks in the stools, and the yield of the progeny as a whole.

In order to use these figures for the selection of progenies the total weight in pounds of stalks, in each progeny, was divided by the number of feet in the progeny, this reducing the yield to pounds of stalks per foot of row. Only those progenies yielding above the average for the comparative section of the field in which the progenies were located were selected for further propagation in new progeny plantings.

In selecting the stools of the best progenies for use in propagation only those stools were selected in which the number of stalks was above the average, or a predetermined standard, and where the average weight of the stalks was above the average for a comparative section of the field. The average weight of stalks was found by dividing the total weight of stalks by the total number of stalks in the progeny.

On this basis the progenies selected for further progeny work were more productive than the average and the stools selected as sources of plant propagation material possessed more and heavier stalks than the average. In several instances in stool selection in the superior progenies an arbitrary standard for number of stalks was decided upon and no stools were selected which did not meet or exceed this standard.

As a rule the best yielding progenies possessed the largest proportion of stools having a uniformly large number of heavy stalks. In some cases all of the stools in the progenies were found to have a larger number and a heavier weight of individual stalks than the average for the section of the progeny fields in which these progenies were located. So striking was this condi-

tion that it was clearly apparent on inspection and it impressed the observer with the profound conviction that such progenies must be inherently superior.

In cutting the seed-pieces from the stalks of the selected stools for planting in new progeny fields all inferior or undesirable stalks in these stools were thrown out and seed-pieces secured from only the uniformly good stalks. The number of seed-pieces cut from each stalk depended upon the condition of the eyes and the growth of the stalks. As a rule there was an increasing tendency to use only one top seed-piece from each selected stalk. In some instances where the eye and growth conditions appeared to be satisfactory, two seed-pieces were cut from each stalk. A few of the progeny fields, planted in 1922, were not harvested this year on account of the fact that the stalks had made such a continuously rapid growth as to be in an unsatisfactory condition for propagation and where it seemed desirable to postpone cutting until the cane became more mature.

After securing the seed-pieces from the desirable stalks of the best stools from the superior progenies for progeny propagation, all remaining good stalks with satisfactory eyes were cut up and used for planting in plantation fields except in a few fields where the poor progenies were eliminated altogether for further propagation. In several instances, the use of these remnant seed-pieces from the progeny fields have given apparently better results than unselected plant material. Only seed-pieces from the left-over stalks having normal and visible eyes should be used, care being taken to avoid all undesirable stalks and those where the eyes are poorly developed or have been injured or become hard and difficult to germinate.

In 1922, most of the progenies were planted according to the so-called snake fashion. With this arrangement where there were more seed-pieces to be planted as a progeny than needed to fill out a row of a water course or plot, the remainder were planted continuously in an adjoining row. In this way some progenies were given one or two end stools while others had none. This condition has proven to be unsatisfactory from the standpoint of comparing and studying the yields and behavior of the progenies.

In the 1923 progeny plantings only full lines have been planted as a rule. If a few extra seed-pieces have occurred, these have usually been discarded or thrown into the general plantings or if a considrable number of additional seed-pieces have been found but not enough to fill out a row, seed-pieces of a different variety have been used to finish the line. This arrangement provides that all progenies start at the end of a row where stakes

or other identification marks can be readily found. It also makes the progeny behavior more comparative from the fact that each progeny has more nearly an equal number of end stools.

Progeny numbers in the fields planted for the first time in 1922 were usually given consecutive numerals. In the 1923 fields where several stools in each of the superior progenies have been planted, as was often the case, the new progeny number has usually been made up of the original progeny number and the number of the parent stool according to its position in the progeny row. For example, if in progeny sixteen, the third stool was propagated, the new progeny number would be 16-3. This arrangement has the advantage of tying together the first and second selections and aids in interpreting the results of the progeny tests. It has the disadvantage of increasing the number of figures to be painted on the progeny stakes or recorded in the notes and records. It seems advisable for the present to continue this arrangement while the number of bud generation is small. Later, it seems logical that new and simplified numbers be given the progenies, particularly after it has been determined that the selected progenies are distinctly and inherently superior.

Maps of the progeny fields showing their location, the position and arrangement of the progenies in the field and the individual progeny numbers have proven to be invaluable in this work. These maps should show the variety, the number and source of seed-pieces, date of planting, method of irrigation and fertilization and any information of interest concerning cultural practices which affect the growth of the plants. With accurate maps it is possible to locate the position and limits of each progeny at any time, a very important matter when stakes or other markers have been lost or moved as has sometimes happened, particularly in the ratoon crops.

In addition to selections from the progeny fields a considerable number of fresh stool selections from the general fields have been propagated in progeny plantings this year on most of the plantations. A continuation of this effort to find superior stools in plantation fields is greatly to be desired. It is not likely that in the rather hurried search and covering only limited areas in 1922, many of the best stools were found. With more information as to methods and standards of selection further search is almost certain to be rewarded by the discovery of distinctly better stools than any yet found.

On several plantations, the interest of the plantation employees and of the school children has been enlisted in the search for superior stools. This cooperation is helpful and beneficial to every one concerned and in our opinion should be encouraged in

every practicable way. Our experience has been that almost without exception, plantation employees have shown an active and intelligent interest in this work when once it has been explained to them and their cooperation requested. Personally, I believe that this method is one of the most effective ones yet proffered for stimulating a keen interest in the improvement of production, through securing better plant material and in securing the cooperation of all those concerned with the success of the plantation work.

The attempt to isolate strains of the Lahaina, and other varieties resistant to disease has shown some very encouraging results. During the present season a systematic search for disease-resistant plants has been carried out on several plantations. The apparently resistant stools have been propagated in progeny fields in order to determine whether or not the apparent resistance is inherent or not and to test the value of the selections for commercial planting. Similar work with other crops has been reported to be a success and this phase of selection work in sugar cane seems destined to become an important factor in rejuvenating varieties which have become decadent by reason of disease attack and for isolating and maintaining vigorous and hardy strains of the important commercial varieties which are highly resistant to diseases.

A considerable number of marked and interesting mutations have been found in the course of this work. These mutations, usually one or two stalks in an otherwise apparently normal stool, are being tested in progeny plantings to determine whether or not their characteristics are transmitted and to ascertain their comparative value for sugar production. In view of the fact that some of the most important of the sugar cane varieties are known to have originated as bud-sports, it seems logical that it may be possible to isolate and propagate additional varieties of equal or greater importance to those already developed as a result of a systematic search for and test of the rather frequent mutations occurring in the fields.

Several plantation managers have stated to the writer this year that in their opinion the improved condition of their crops was largely, if not wholly, due to their use of superior plant material secured from their best fields. Some of the managers, in addition to carefully selecting the best fields for sources of plant material, have organized this work so that there is an inspector with each cutting crew whose business it is to supervise this work and to see that seed-pieces are cut from only healthy and desirable stalks, and an inspector with each planting crew who inspects the seed-pieces and eliminates any apparently undesirable

ones which may have been accidentally cut and included in the seed supply. With rigid inspection, and supervision during cutting and planting, a more uniformly desirable lot of plant material has been secured and used than has heretofore been the case.

The stool selections for the first progeny plantings were made upon the basis of their comparative development and without any knowledge as to whether or not their characteristics were inherent or the result of environmental influences. In the progeny fields it has been possible to distinguish and pick out what we believe to be inherently superior progenies when the development and production of the stools have been uniformly better than the average. The selection and propagation of the best stools of these superior progenies is the most important step in this work. On many plantations this work has been done this year for the first time. The results of this effort are likely to be encouraging and to pave the way for the systematic production of adequate supplies of progeny improved plant material for use on all of the plantation fields within the next two or three years.

The writer wishes to express his personal appreciation for the kindness, consideration and cooperation on the part of his associates in the Experiment Station, the management and employees of the plantations and all others with whom he has come in contact in the course of this work. The conduct of this work during 1923 has been encouraging from a number of standpoints, including the successful introduction and use of systematic methods of studying progeny behavior and for the selection of the best stools of the superior progenies for propagation. With accumulating knowledge of sugar cane plant characteristics and their behavior when propagated the practical value and utilization of bud selection for improved efficiency will be more fully appreciated and the desired results will become more certain of realization. Enough evidence has been observed to warrant the opinion that this work is an important factor in sugar production.

A Comparison of Bud Selected Strains

(From a report by J. A. Verret)

Bud selection has been continued this year on a large scale. Nearly all plantations now have some areas devoted to this work. We believe definite progress has been made, although it is yet too early to point to any conclusive results.

A little test harvested at the Makiki plots gives very encouraging results. The test consisted of a number of so-called types selected by W. W. G. Moir. At the second selection we planted

five progenies checker-board fashion with five repetitions of each. When harvested at about one year old, one of the progenies, Progeny No. 1, was in all cases better than any of the others growing next to it, while Progeny No. 2 was, two plots excepted, always poorer than any other adjoining one. Moir's old notes give No. 1 as a "good type" and No. 2 as a "poor type." The test is being continued on a larger scale.

To get the most from bud selection means a great deal of hard work, and one should not get discouraged if it should happen that his selected progeny field does not appear any better than the ordinary plantation cane. It may be that only one or two of the progenies are mutations and better than the rest, and it will take several crops to isolate these superior strains. H 109, for instance, is of recent origin, and it may well be that but few mutations have taken place. We get striped sports of H 109, but they are not very common. Assuming that "high yielding sports" are not any more common than striped sports, one can readily see that a large number of stools have to be handled to get what we are after. But after we have once isolated the good strain, the rest is simply a matter of spreading it as fast as possible.

On account of the difficulty of recognizing the type we want, we are now basing our selections, after the first stool selection, on the weight of cane per foot of row of each progeny, and taking only those above a certain standard based on the average of the lot being handled. This method is explained in detail in a report by Mr. Shamel.

In going about the plantations we have noticed that in general careful attention is being given to the seed used for regular planting. Many plantations are making a rather careful selection of all seed used. We believe this to be a great step in advance, and that this improvement alone is worth all our efforts in bud selection lines. Let us hope that this will continue and that even greater care will be given to all material used for planting. It seems to us that unless a field is well prepared and good seed is used, maximum results will not be obtained, no matter what is done afterward.

Substations on Oahu

(From a report by J. A. Verret)

Waipio Substation

General Conditions:

Conditions at Waipio substation were good during the year, all our fields being in satisfactory condition, excepting that during part of July and all of August we were rather short of water. Irrigations in August averaged over twenty days apart. We have a total of 25 acres planted to selected progenies. It is too early to say how many, if any, of these progenies will prove superior to the average run of H 109 at Waipio. We plan to carry the better ones, as determined by weight, for several crops, at the end of which time any outstanding ones could be rapidly spread.

We select all our seed at Waipio, using only good, well developed, carefully cut seed. This seed is planted, without soaking, within 36 hours of cutting and irrigated at once. As a result of this we get a full stand very quickly without any replant. We do not space our seed. We believe we are getting big returns from our cane using only choice seed.

1923 *Crop*:

The 1923 Crop amounted to 962 tons of sugar, the largest crop yet raised at the Waipio substation.

The details of the crop are given in an appendix to this report.

The average age of the crop was 18.3 months and produced sugar at the rate of 0.558 ton per acre-month, with a quality ratio of 8.32. We believe this very good considering the fact that one-third the area was from our pali lands.

We applied nitrogen at the rate of 3.6 pounds per ton of cane, or 30 pounds per ton of sugar produced. This is not by any means too much, as the cane plant is generally considered to use at least 3.5 pounds of nitrogen per ton of cane produced.

1924 *Crop*:

The 1924 crop will harvest from 76.63 acres, 10.51 plant, 32.86 long ratoons, and 33.25 short ratoons. From this area we estimate a yield of 775 tons of sugar.

Seedlings:

Some of the newer seedlings are showing up fairly well at Waipio. H 8958, H 89102 and H 8994 are planted to fair sized plots and are being carefully observed, and will be spread in our plantings next year into regular field experiments. We also have some of the better Wailuku seedlings growing. We plan to plant a small plot of Ewa seedlings from seed to be sent from Makiki plots.

The Waipio Field Work

(From a report by F. A. Paris)

The results of this year's experiments at Waipio are published in our monthly records. They have in their details a local importance. Most of them in the last few years have been studies as to the influence of intensive cultivation methods on sugar cane production under average conditions for makai fields in our district. We have attempted to apply the new means put at our disposal for increasing production, correct natural defects, and take due advantage of environment. We have found that H 109 variety responds strongly to intense feeding or any physical improvements of the environment. In the resumé we have gained a proper knowledge of the habits and treatment of our canes. We have studied our soils. With better implements at our disposal we can prepare them better, and so provoke a larger root development, greater feeding capacity, and greater vitality. It is not so much the actual results obtained at Waipio in tons of sugar per acre that count, but the possibilities which our work show for a constant improvement of our field methods. They point out the importance of taking time into consideration and not only acreage in producing sugar and lowering the cost of production.

We realize, gradually, the necessity of calculating every move in the field so as to take full advantage of favorable climatic conditions and of optimum growing periods. It means careful watching of our soils and plants, we must get to feel at once when anything is wrong with either of them. Like real farmers, we must feel with our feet and see with our eyes, the physical conditions of a newly plowed field, the needs of a young crop. By perfecting our field methods we gain interest, the work becomes a hobby. The more we master the details the more we acquire the knowledge indispensable to financial success.

It would now be interesting if we could carry on our studies on a large scale and, in collaboration with the plantations, ascer

tain how wide an application can be made of the information we have gained on a comparatively small scale at Waipio.

Several new methods are based on fundamental principles which do not vary with the locality; others are determined by experimental work. We come to the conclusion that any plantation or group of plantations under similar conditions should carry on:

1. Permanent plant food tests.
2. Nitrogen tests to determine the limit of nitrogen fertilization, which is, most everywhere, the main factor for improving yields and minimizing field production costs.
3. Seedling stations.
4. Mass selection of seed.

These observation fields should be large enough to show plainly to any field man the right thing, and they should be laid out so as not to disturb plantation routine at any time. Mass selection of seed is essential. Among the best established strains of plants or animals, weak or inferior specimens appear, and on their prompt elimination depends the maintenance of the desirable strains. I have worked out a practical plantation mass selection scheme which will be submitted for consideration.

I have no doubt that a careful study of conditions for each plantation or group of plantations would lead to the adoption of field methods which would regulate our yields and save money, which would make the future safer.

In the seedling line we have a collection of types which may enable us to provide the various islands with canes of commercial value. These types have been sorted at Waipio and shipped where we feel they belong.

Manoa Substation

(From a report by J. A. Verret)

We now have twenty acres under cultivation at Manoa, all of which is devoted to cane varieties, mostly new seedlings. Forty thousand 1923 seedlings were planted out this year. Of the older seedlings, 1,250 were harvested, and the better ones planted to larger areas. Seed of 250 of these were sent out to different plantations. The large majority of these were D 1135 and Tip seedlings, with a few Badila.

We have growing at Manoa all of the best Kohala seedlings and shall have fairly large amounts of seed from these for distribution next spring.

Field Experiments on Hawaii, Kauai and Maui

This work has been in charge of Mr. Verret, who has had the cooperation of Messrs. Pratt, Paris, Stender, Jennings, Markwell, and Broadbent.

Cooperative Work With Plantations of Hawaii

(Not including Kohala District)

(From a report by J. S. B. Pratt, Jr.)

Experiments Harvested:

Thirteen experiments were harvested, consisting of three cultivation, one green manuring, one variety, and eight fertilizer tests. In addition, several others were harvested by the plantations themselves, as at Paauhau and Honokaa. Most of these have been discontinued. One more experiment remains to be harvested at Pahala.

Potash experiments for the Hilo district harvested this year and previously definitely show the value of potash from Olaa to Hakalau up to 150 pounds K_2O.

The lupine experiment at Hamakua Mill showed no value from the lupines, but will be repeated to test the residual effect.

Cultivation experiments all indicate no benefit from cultural operations aside from a cheaper means for weed control.

New Experiments:

Fertilization questions for the Hilo district have been fairly well answered during the past two years, and with the plantations placing men on selection and experimental work, it was felt that the work of the near future should be to cooperate with the plantations, especially on the bud selection and seedling work, rather than to lay out a lot of new fertilizer tests.

However, to answer important questions on the quality of juice, two experiments were laid out at Pepeekeo and one at Hilo Sugar Company on the 1924 crop, testing the effect of a spring dressing against none. Also, to see what effect the potash applied in the second season had on the quality of juice, a test was laid out for the 1925 crop at Hilo Sugar Company, with potash applied in part in the second season as against none the second season. A test on 1, 2 and 3 applications of potash was

laid out at Hilo Sugar Company for the 1925 crop to answer the same question.

Selection Work:

This was handled by the plantation selection men. Our work was confined to developing better methods of studying the individual progenies by weighing at harvesting, by studying data, etc., and cooperating with these selection men in meeting their problems. A few individual progenies stand out, but they will have to be carried on several generations before their definite behavior is known. The progenies at Pepeekeo and Hamakua Mill Company were harvested by Mr. Neil Webster, of the Station staff. He also laid out several new progeny areas.

Seedling Work:

Realizing the necessity of obtaining another cane to equal or better Yellow Caledonia, we concentrated largely this year on seedling work. Caledonia is still excellent in the Hilo district, but we should have a cane to rotate with it, or give us better juice. Seedling work is slow and we must look ten years ahead. A large number of seedlings were sent out to the Hawaii plantations this year. H 8958 is already making an excellent start. Onomea shows good results from H 472, H 456, Wailuku 2 and Wailuku 9.

We consider Wailuku 9 an excellent cane for further trial in the Hilo district. We will send out seed of this variety this coming planting season to all of the Hawaii plantations.

Some 250 seedlings for mauka land were sent for trial at Honokaa and Pahala.

Honomu has some excellent seedlings of their own propagation, and we are assisting them in the selection.

The same applies to Hilo Sugar Company. We harvested a field test this year where one seedling in particular, of Lahaina parentage, gave an excellent yield and juice.

Work for the Coming Year:

There are thirteen experiments to harvest next year, with fertilization due for the 1925 crop experiments. We will concentrate on seedling work. We wish to establish seedling plots on the various plantations, from cuttings sent from the Makiki Station after some degree of selection. This will eliminate the preliminary seedling trials on the plantations, which so often make a ragged showing.

Definite variety tests with checks of Yellow Caledonia for makai and D 1135 for mauka will be laid out, for this is the best means to definitely prove a variety. The selection work will be similar to this year, with a more rigid weeding out of the poorer progenies.

Agricultural Extension Visits:

Numerous trips were made during the year by members of the agricultural department on extension work, in bettering our acquaintance with plantation conditions, and assisting in any problems. The actual carrying out of the fertilizing and minor details of the experiments can be largely done by the plantation experiment men.

Cooperative Work With Plantations of the Kohala District

(From a report by W. C. Jennings)

Propagation of new seedling varieties has been given first consideration in the work for the past year, and as a result of this 23,000 seedlings have been put out in the field.

Much progress has been made also with seedlings from propagations of previous years, especially at Kohala Sugar Company, where at least four varieties are in a fair way of becoming commercial canes.

Standard varieties are receiving attention, and several tests comparing their adaptability to different conditions of soil, moisture, and elevation have been laid out.

Bud selection has taken second place in time and attention received. From the first field tests of the 1922 selections, 884 progenies covering five acres on three plantations were harvested; from these 272 progenies were selected, by the weight per foot and weight per stalk method, for planting in the second field tests. Three hundred and eighty-nine 1922 selections are being carried over to next year also, which, with 500 additional parent stools, selected this year and put out in progeny plantings, will make a total of 1,180 progenies to be harvested in 1924.

Experiments to the number of sixtyy-one are now running in this district. Of these, twenty-three are regular field experiments, and thirty-eight are observation tests such as seedling stations and progeny fields. These experiments and observation tests are based on a number of agricultural problems, but we are especially working for:

(1) The development of hardy, disease resistant varieties of cane, suitable for growth under a number of adverse conditions.
(2) Improvement of standard varieties through selection.
(3) Determination of nitrogen, phosphoric acid and potash requirements of Kohala soils.

Seedlings:

A special report is being prepared on the 1923 seedling propagation work which will be but briefly taken up in this report.

Special attention was given to securing Striped Tip seedlings in the Kohala work this year, and 25,000 germinations were secured, of which 13,000 were placed in the field. The probability is that these are mostly Striped Tip x D 1135 and Striped Tip x H 109 crosses, as the tassels were selected in localities favorable to such crosses.

From 500 Badila germinations 220 seedlings were set out in the field.

In the table below, which gives the number of seedlings actually set out in the field, the first named variety is the female parent, and the second is the probable male parent:

From Kohala tassels:

Striped Tip x D 1135	12,200
Striped Tip x H 109	800
H 109 x Striped Tip	1,100
H 109 x ?	1,000
D 1135 x Striped Tip	90
Badila x ?	220

From Oahu tassels:

H 1801	2,600
H 5978	2,000
H 109	2,780
D 1135	110
Lahaina	100

These seedlings were set out by the plantations as follows:

Niulii Mill and Plantation	2,000
Halawa Plantation	2,000
Kohala Sugar Company	6,700
Union Mill Company	4,100
Hawi Mill and Plantation	8,200

Wherever practicable among these seedlings, the first selections for planting in second field tests will be made in year-old cane.

Most of the seedling work in the district hitherto has been confined to Kohala Sugar Company, and as a result of their work this plantation has a number of canes that compare well with the commercial varieties.

Of the seedlings of the 1917 Series—Hawaii Propagation, the plantation has been spreading K 115 for two years, and K 73, K 107, K 117 and K 202 as rapidly as possible this year. Several acres have also been planted to K 101 and K 493, and smaller areas to a few more of the most promising canes. K 73, K 107, K 117 and K 202 are very vigorous canes of the Tip type and show every indication of being suited to adverse conditions, but it should be borne in mind, when considering any of the Kohala seedlings, that they have not yet been grown in direct competition with similar types of commercial canes.

Of the 1920 seedlings (Hawaii propagation), No. 1003, a Lahaina seedling with many D 1135 characteristics, is the outstanding cane and deserves further attention.

It is planned to concentrate on Uba and Badila crossed with other varieties in the 1924 seedling work. Several areas of Uba were planted in different parts of the district this year with the expectation of getting tassels for the 1924 work. One experiment was laid out with Uba, Badila, ten native varieties, and several commercial canes with the hope of securing valuable crosses.

It is also planned, if good tassels are available, to supply seedling nurseries in Hamakua, Oahu and Kauai with Badila and Tip tassels.

Bud Selection:

The selection work was carried out along the lines recommended by Mr. Verret and Mr. Shamel on their trip to Kohala in June of this year. Two hundred and eighty-seven Yellow Tip, 268 Striped Tip, and 329 D 1135 progenies were harvested, data recorded and selections made for planting in fields tests 2.

In the work with Yellow Tip and D 1135 progenies, no superior types were recognized, but it is believed that we have a superior type of Striped Tip, the characteristics of which are large circumference stalks of more erect growth that are particularly free from adventitious roots. Whether or not this be a distinct strain should be indicated in the 1924 selection work, as twelve stools of this presumed type were put out in progeny plantings to be harvested then.

At present it is planned to continue with the same selection methods in the 1924 work.

We now have 1,945 plant and 960 first ratoon progenies under observation.

Fertilization:

There are four plant food requirement experiments and four amount of nitrogen to apply experiments to be harvested with the 1924 crop. These experiments should give a fair indication of the nitrogen, phosphoric acid and potash requirements of Kohala soils.

One plant food and five nitrogen experiments are planned for 1925.

Field Experiments:

Of the twenty-three regular field experiments, eleven are in the 1924 crop, and twelve with the 1925 crop. Most of the seedling stations and progeny fields that are classed as observation tests will be harvested and selections made for further field tests during the 1924 season.

Harvesting Results:

The 1923 experiments were harvested. At Hawi Mill & Plantation Company a large off-barring experiment gave negative results. At Union Mill Company a small unmapped nitrogen experiment showed gains up to the limit applied, which in this case was 137.5 pounds.

Field Experiments on Kauai

(From a report by O. C. Markwell)

There are forty-three active experiments on Kauai. Of these Kilauea Sugar Plantation Company has seventeen; Koloa Sugar Company, sixteen; Grove Farm Company, Ltd., seven, and Lihue Plantation Company, three. These have an aggregate acreage of 108.062; Koloa Sugar Company, 40.602; Kilauea Sugar Plantation Company, 30.68; Grove Farm Company, Ltd., 18.68; and Lihue Plantation Company, 18.1.

In the 1924 crop Koloa Sugar Company has ten experiments comprising 25.45 acres; seven experiments in plant cane, one in third ratoon and two in fourth; 1925 crop consisting of six experiments, 15.96 acres, all in plant cane.

Grove Farm Company, Ltd., has no experiments in the 1924 crop. In the 1925 crop there are seven experiments, 18.68 acres; six of these are in plant cane and one is in first ratoon.

Only three experiments, a composite area of 18.1 acres, all in first ratoon, are carried on at Lihue Plantation Company.

At Kilauea Sugar Plantation Company the 1924 crop includes 21.51 acres giving rise to eleven experiments, six in plant cane and five in first ratoon. Four experiments, consisting of an area of 9.17 acres, make up the 1925 experimental crop.

At this writing 65.962 acres of the 1924 crop on Kauai and 43.0 acres of the 1925 crop are to be harvested as experimental cane.

New Experiments:

Since August, 1922, sixteen experiments have been laid out at Koloa, eight at Kilauea, and six at Grove Farm. In August, 1922, the Koloa Sugar Company stood in need of experiments, having only three active ones, two of which should rather have been classed as observation tests. Today Koloa is fairly well supplied. In the choosing of sites for all these experiments, special attention was paid to soil types and local conditions. Experiments based on amounts of nitrogen, phosphate and potash are found mauka, makai, and in an intermediate locality. Only one variety test has been laid out at Koloa.

The work in new experiments at Kilauea was restricted to phosphates and varieties. In the phosphate experiments raw rock and bone char; while in the varieties, Yellow Tip, Striped Tip, Uba, Badila, H 456 and H 109 were used.

The experiments laid out at Grove Farm pertained to flowers of sulfur and inoculated sulfur as a catalytic fertilizer. Both mauka and makai fields were treated with sulfur.

Experiments Discontinued or Discarded:

Koloa Experiments No. 1, 2, 3; Lihue 1, 2, 3, and Makee 1, 2, 3, were harvested and will be discontinued. The areas of the Experiments Nos. 1, 2, 3 at Lihue and Makee now lie fallow.

Because Experiments Nos. 2 and 3 at Koloa were made up of an insufficient number of repetitions and the areas were so irregular that the actual areas could not be determined, they proved unsatisfactory and will be discontinued. The harvesting results of Experiment No. 1, Koloa, were well defined and its continuance was considered unnecessary.

At Kilauea Sugar Plantation Company Experiments 38, 40, 43, 44, 34, 49, 50 and 51 were discontinued.

Harvesting Results:

The harvesting results of Makee Sugar Company's Experiment No. 1, Forms of Nitrogen; Experiment No. 2, Amount of

Nitrogen; Experiment No. 3, Molasses Ash, showed that the economic limit of nitrogen in nitrate of soda was about 150-175 pounds and that some response was obtained from potash. More work in potash is recommended.

Experiments Nos. 1, 2, 3, Lihue, pertaining to value and amounts of nitrogen, value and amounts of reverted phosphates, plant food gave no marked benefits, and since the ratoons were poor the field was put in fallow.

At Koloa Sugar Company Experiment No. 1, lying in the Puuhi section, decidedly makai, showed a distinct benefit from nitrate of soda compared with a mixed fertilizer. As a result of this experiment portions of Puuhi, which are similar in soil type to the above area, are fertilized as this experiment indicates they should be.

During the past year Knudsen Brothers plantation has received attention. Soil samples were taken for Mr. Stewart and special consideration was given the variety and fertilizer questions.

The ten-acre experiment of the "H 400" varieties compared with H 146 and Yellow Caledonia at Grove Farm proved disappointing, as none of the H 400 varieties were outstanding.

Future Experiments:

Experiments of the immediate future should be of the variety type. At Makee Sugar Company it might prove profitable if experiments pertaining to potash were laid out.

Seedlings:

A report on seedlings on Kauai has been published in the October "Record" and a brief summary only is given here.

There is a total of 6,953 Kauai seedlings now growing on that island. In addition to this a number of the more promising ones from the other islands are being tried.

Of the Kauai seedlings, 153 have gone through four selections. These especially are being spread and carefully watched. In this work we are paying particular attention to ratooning. Above all things Kauai needs a good strong ratooner. Working along these lines we plan trying out all of the better Tip, Uba and Badila seedlings.

Cooperative Field Work With Plantations of Maui

(From a report by Frank W. Broadbent)

The following is a general recapitulation of the field experimental work done on Maui during the past six months by repre-

sentatives of the Experiment Station, H. S. P. A., with the co-operation of the plantations, or by the plantations themselves.

Three lines of work have been carried on: field experiments, seedlings, and progeny selections. The details of what has been done in each of these lines will be taken up by plantations below.

Hawaiian Commercial and Sugar Company,

Lahaina Progeny Selections:

In Field "A", 10.5 acres of first selection Lahaina cane progenies were planted by Mr. Stender during July. These 684 progenies he selected from ratoon stools in Field "L".

In the same Field "A" are 47 second selection Lahaina progenies. These occupy 5.3 acres and were selected by Mr. Stender (using the cutting, counting and weighing method) from 142 progenies that had been originally selected and planted by G. B. Grant in September, 1922. The "left-overs" from these re-selected Lahaina progenies are planted separately and fill 14.6 acres.

H 109 Progeny Selections:

In August of last year, G. B. Grant selected some 1,800 stools of H 109 and set them out as progenies in Field 15. These occupied 15.3 acres. About ten acres of this area were reselected during August by Mr. Stender and the writer. Weights only were taken and a good number of progenies not scaled because of evident poor quality. In all, 941 progenies were weighed and on an average standard of 14.31 pounds per foot, 137 were taken for further propagation. These were planted in Field 2 and cover an area of 8.9 acres. Two additional progenies of very low weight per foot were also planted out as a matter of interest to note whether they will retain this character.

Seedlings:

Field Test 5 of 54 Wailuku (M. P. 1917) seedlings in Field "F" was harvested during May for cane weights and juice qualities. This area had been planted in October, 1921, and nineteen of the varieties had been partly cut for seed in 1922 and extended to Field "D" as Field Test 6.

Field Test 6 covered about 1.5 acres and the nineteen varieties therein were cut during July and August and extended over sufficient areas to obtain good harvesting tests two years hence. Field "A" contains 15.6 acres of these varieties, Field 15 has 5.2 acres and Field 1 about 19-20 acres.

Ten varieties (178 bags) from the above F. T. 6 were sent to Pioneer Mill Company. Another ten varieties (22 bags) were sent to the Olowalu Company. Two boxes of seed containing ten of these seedlings were shipped to the Kaeleku Sugar Company.

Two lots of "H" seedlings were received from Honolulu and planted by the plantation in fields "A" and "L". In Field "L" are H 8949 and H 8994. In Field "A" are H 8993, H 8948, H 8954, H 8958, H 8961, H 8965, H 8978, H 8988, H 8993, H 89102, H8969, H 8942, H8984 and H 8973.

Pioneer Mill Company,

Field Experiments, Crop 1923:

The group of experiments in Field B6-L was harvested in February by J. S. B. Pratt, Jr. Of this group four dealt with fertilizers and one was a variety test.

These five experiments are to be continued in the second ratoons for the 1925 crop. Total area of five tests is 13.69 acres.

Field Experiments, Crop 1924:

For this crop five tests are now running. These are located on different parts of the plantation. They deal with fertilizer questions.

The total area of the five tests is 11.1 acres.

Field Experiments, Crop 1925:

Besides the five experiments being carried on in second ratoons in Field B6-L (13.69 acres), sixteen new experiments are at present laid out for the 1925 crop. Two of these are cut-back tests and the remainder fertilizer. These latter are laid out in what has been chosen as five typical cane environments to be found on the plantation.

The total area of the new tests laid out for the 1925 crop is about 31 acres. To this must be added the area of the ratoon experiments, making a total test area for the crop of about 45 acres.

Seedlings:

A layout comprising some 130 seedlings has been put in covering some 10-12 acres in various locations or "stations" on the plantation in Fields O-6, O-7, G-2, B-5 and 32.

Part of this planting is from thirty seedlings reselected by W. W. G. Moir and the writer from an original planting (January, 1919) or O. P. 1915 and 1917 seedlings in Field 0-10. The 1917 seedlings selected are Nos. 11, 33, 46, 60, 78, 87, 134, 210, 240,

242, 273, 277, 284, 287, 299, 300, 336, 347 (Ewa 800), 384, 389, 394 (Ewa 801), 719 and 746. The 1915 propagation seedlings selected are Nos. 5908, 5909, 5946, 5949, 5965, 5974 and 5978.

Thirty seedlings were reselected by W. W. G. Moir from a mixed planting (O. P. 1915, 1917; M. P. 1917 and unknown) or varieties in Field MA-1. Eighteen of the above thirty that showed promise, but the identity of which could not be made certain, were given letters. Two 1917 seedlings (Oahu propagation) taken were Nos. 74 and 78. Seven Wailuku (M. P. 1917) seedlings taken were Nos. 153 (original number), W 19, 51, 52, 53, 60 and 59.

Twenty-one Wailuku seedlings have been planted out by the plantation, certain ones over considerable areas. This seed came from the Wailuku Sugar Company and the Hawaiian Commercial & Sugar Company. Among these are: Wailuku 1, 2, 4, 5, 6, 9, 10, 11, 12, 13, 15, 17, 47, 49, 50, 55, 56, 61, 62 and Nos. 20406 and "XX".

From Honolulu the plantation has received twenty-two "H" seedlings and two others as follows: H 416, 463, 471, 472, 1801, 5978, 8949, 8994, 8922, 8961, 8973, 8933, 8942, 8948, 8954, 8958, 8965, 8969, 8973, 8988, 8993 and Waipio 5 and White Bamboo.

Twenty-five Ewa seedlings recently received by the plantation are: Ewa 177, 19, 225, 325, 362, 371, 378, 380, 386, 387, 406, 421, 509, 555, 569, 570, 700, 710, 712, 720, 731, 732, 737, 740 and 759.

Progenies:

All of the progeny selection work has been done by the plantation under the direction of W. W. G. Moir, of the Pioneer Mill Company. Over 500 progenies have been planted out and cover about thirty acres.

From the progeny area in Field B-2 six progenies have been taken for further trial. From Field B-3 about forty-five progenies and from Field B-5 sixty-four progenies. All of these "B" field progenies are H 109.

In Field 33 one hundred and thirty-eight H 109 progenies have been extended.

Six Lahaina cane progenies were extended from Field B-5 and more have been started.

Two hundred and fifty new D 1135 progenies have been started.

Twenty-five H 109 progenies were secured from the Wailuku Sugar Company by arrangement between the plantations. These progenies are from the H 109 progeny area, Field 67, W. S. Co., which the latter company reselected this year.

Olowalu Company,
Seedlings:

Ten Wailuku seedlings (M. P. 1917) were planted during July and August. There are from eight to fifteen lines of each located in the "Miaki" field. The numbers of these varieties are: W 1, 2, 4, 12, 15, 50 and Nos. 20406, 41411, 52715 and "XX". This seed came from Field Test 6, Field "D", Hawaiian Commercial and Sugar Company.

Progenies:

Fifteen reselected progenies of H 109 were extended during August into the "Miaki" field, covering about 0.75 acre. These progenies were reselected from the seventy progenies in the "Ah Ki" field. This latter area was planted in 1922 (and never mapped) with progenies selected from the "Julio West" field by W. W. G. Moir. The selected stools in the "Julio West" field coming from the Wailuku Sugar Company.

Maui Agricultural Company,
Field Experiments, Crop 1923:

Three field experiments in field 83 were harvested during June. One was a variety test, two dealt with fertilization.

These tests were harvested off first ratoons and are now discontinued. No experiments are running for the 1924 crop nor have any new tests been laid out for the 1925 crop.

Seedlings:

Two field tests (F. T. 2) of 460 Maui Agricultural Company 1920 Maui propagation seedlings located in Fields 3 and 94 were harvested during June. Weights were taken of all the good ones and juice analyses of all that went over twenty pounds cane per foot of row. Both field tests are to be watched for ratooning qualities in picking varieties to carry on for further tests.

Two and one-half watercourses of Wailuku 54 (M. P. 1917) and a few lines of W 4 and W 9, located adjacent to the selected seed area in Field 3, were cut up for seed and planted on a larger scale so as to obtain a good harvesting test two years hence.

A box of White Bamboo seed received by the plantation is planted in Field 95 and a consignment of fifteen H 109 seedlings (O. P. 1918) is planted in Field 81. These seedlings are: H 8933, H 8942, H 8948, H 8954, H 8958, H 8961, H 8965, H 8969, H 8979, H 8973, H 8984, H 8988, H 8993, H 8994 and H 89102.

Progenies:

Over 500 H 109 progenies in the progeny area, Field 3, were cut, weighed and reselected during July and part of August by Messrs. Nicoll and Steven, of the plantation. This is the third selection of these progenies, the previous two having been made by W. W. G. Moir.

The 170 progenies taken for further propagation are planted in the same field and occupy approximately ten acres.

Twenty Lahaina cane progenies located in this Field 3 area were also reselected and seven of them carried on.

The left-overs are planted in a body in the same Field 3.

In Field 82-A, 178 Lahaina progenies were reselected and 71 carried on. These are planted in Field 81, covering 3.25 acres.

The left-overs from the Field 82-A areas have been planted in separate areas on several fields.

Wailuku Sugar Company,
Field Experiments, Crop 1923:

The old fertilizer experiments Nos. 1 and 3, Field 98, were harvested in March with the object of noting residual effects. Experiment 1 was originally an amount of nitrogen test and Experiment 3 was a number of applications test of a given amount of nitrogen.

Experiment 13, Field 70, plant food requirements, was harvested in March.

Experiment 12, Field 17, plant food, was harvested during the last of March and first part of April.

Experiment 15, Field 100, plant food, was harvested by H. K. Stender in June.

Experiments 1 and 3 have now been plowed up and the other three are in ratoons, but are discontinued.

Field Experiments, Crop 1924:

Experiment 16, Field 89, a variety test, is now running for next year's crop. The varieties compared are: H 109, W 1, 2, 3, 4, 5, 9, 10, 11, 12 and 13.

No new experiments have been laid out for the 1925 crop by the writer.

Seedlings:

Eight boxes of Ewa seedlings (Nos. 177, 378, 380, 509, 710 and 720) were received in April and planted in Field 98. Each variety is separated by three lines of H 109 as a check.

In May, the following Wailuku (M. P. 1917) seedlings were shipped to Ewa Plantation Company: one box each of W 1, 2,

4, 5, 10, 11 and 13. A similar shipment was made to the Waimanalo Sugar Company and five boxes of W 2 sent to Kahuku Plantation Company.

Seedling Station 4, Field 100, of Wailuku Seedlings (1917 propagation) was harvested in June by Mr. Stender for weights and juice qualities except in the case of those varieties that had been cut for seed previously.

Mr. Stender also assisted in harvesting Field Test 2 of the four hundred and twenty-one 1920 propagation seedlings in Field 100. Each seedling was weighed, sticks counted, and the juice qualities of those going over 20 pounds of cane per foot of row taken. In conjunction with these results the ratooning qualities of these seedlings will be noted when future choices are to be made.

The plantation has extended the areas of several of the seedlings. Data on this is not as yet available as the maps have not been finished.

Progenies:

The single-eye planting of H 109 and Badila in Field 100 was stool-selected by the writer and Mr. Marciel, of the plantation, during April. One hundred and seventy-one stools of H 109 were selected and planted in Field 98 as progenies. Twenty-six stools of Badila were taken.

The H 109 selected seed areas, Field 67, were cut, weighed, and reselected by the plantation, the progeny plantings made in Field 98. Figures and maps of this work are not on hand with the writer as yet. This work was started when Messrs. Shamel, Agee and Verret visited Maui in May. Mr. Marciel, of the plantation, carried it on and he was later assisted by Richard Penhallow.

Some seed of certain progenies of this area was shipped to Pioneer Mill Company by arrangement between the plantations.

Further selection work has been done by the plantation in different varieties. No data forthcoming on this as yet.

In May, ten boxes of Striped Mexican seed were shipped to Union Mill Company. Six boxes of this were from selection cane and the remainder plantation run.

Kaeleku Sugar Company,
Seedlings:

In July, three boxes of seed were shipped to the above company. Two of these contained five varieties each of Wailuku seedlings Nos. W 1, 2, 4, 12, 15, 50 and 20406, 40510, 41411 and "XX". The third box contained H 109 seed that Mr. Gibb had asked for as he desired to obtain a different strain of that cane.

From Honolulu a shipment of H 468, H 8929, H 8949, H 8961, H 8978, H 8983 and H 8993 was sent during the same month.

Pineapple Work

(From a report by G. R. Stewart)

The work for the Pineapple Packers' Association has been carried on during the past year. Mr. E. C. Thomas has devoted his time to their investigations and miscellaneous problems. He has lately been assisted by Mr. John Horner. We have two major research problems under way.

Study of Composition of the Pineapple Plant

We are continuing our work on the composition of the pineapple plant at different stages of growth. Regular samplings have been made at three-month intervals since the plants started to grow a year and a half ago. We are making two sets of analyses. One set is from plants grown under mulching paper and the other from an adjoining plot without paper. The paper plots still maintain their lead in growth and have shown a correspondingly greater absorption of plant nutrients from the soil. Up to twelve months of age the paper plots had taken up the following amounts of plant food per acre: nitrogen, 165 pounds; lime, 59 pounds; phosphates, 34 pounds, and potash, 526 pounds. The no-paper plots had used 100 pounds of nitrogen, 41 pounds of lime, 22 pounds of phosphates and 345 pounds of potash.

The work will be continued with the ratoon crop. This investigation will form a valuable contribution to our knowledge of the growth of the pineapple plant.

Growth of Pineapples in Nutrient Solutions

The pineapple plant makes an ideal growth in water cultures. This permits of an infinite variety of experiments under controlled conditions, varying the quantity and proportion of nutrients and making combinations which will throw considerable light upon the nutrition of the plant. We now have a study under way which is designed to throw some definite light upon the action of the ferrous sulfate spray, and the exact change which manganese makes in the plant's absorption of nutrients. The plants are making an excellent growth and should yield definite analytical results showing the changes in composition caused by the various treatments.

Miscellaneous Laboratory Analyses—Pineapple Work

Besides the above investigations we have analyzed a considerable variety of miscellaneous samples for the various canneries and plantations. These have included fertilizers, canned pineapple, fruit juices, fruit syrups, soils, waters, and waste products.

Essential Factors of Sugar Production—Sugar Cane Growth Values

(By H. P. Agee)

In the manufacture of sugar we weigh the juice and through laboratory analyses proceed to measure the sugar or sucrose entering the factory. Cane weights, juice and bagasse data enable us to measure the extraction of sugar from the cane. On its way through the manufacturing process we carefully measure all known losses of sugar in filter press cake, molasses, etc. We do these things now as a part of the routine of the day. We are so accustomed to these measurements that no progressive mill will do without them. We require such measurements because in revealing losses they aid in their control and correction.

New inventions or processes that, at reasonable expense, will increase extraction or recovery by one per cent or an appreciable fraction thereof are generally given their due consideration.

As raw sugar proceeds through the refinery it is again measured at every available stage, for to know where losses exist is to be able to hold them in check.

Working back from the cane to the field, sugar losses have again been measured or estimated for the period that intervenes between burning or cutting a field to the milling of the cane. We have, as a rule, less concern about big losses here than we do about smaller losses from accidents, such as when tanks overflow, because it is a natural failing to pay less heed to the invisible menace that quietly robs us of our profits than to the visible one that so effectively commands our attention. We are, however, coming more and more to recognize the large loss from delay in milling by virtue of the fact that we are coming more to measure it and realize its existence.

This report suggests the recognition of other and greater losses than those already mentioned. These losses would be appalling if we could express them in fitting terms, yet they cause us no alarm because we do not know how to measure them. In fact, we are just beginning to discuss their existence and to conduct research that will find ways to measure them, and discover means of holding them in check.

These investigations go beyond cane, the raw material of sugar manufacture. They deal with the essential factors of sugar production, the raw materials of our sugar cane agriculture.

In a report a year ago this subject was presented by the present writer who said: "The basic resources of a plantation, aside

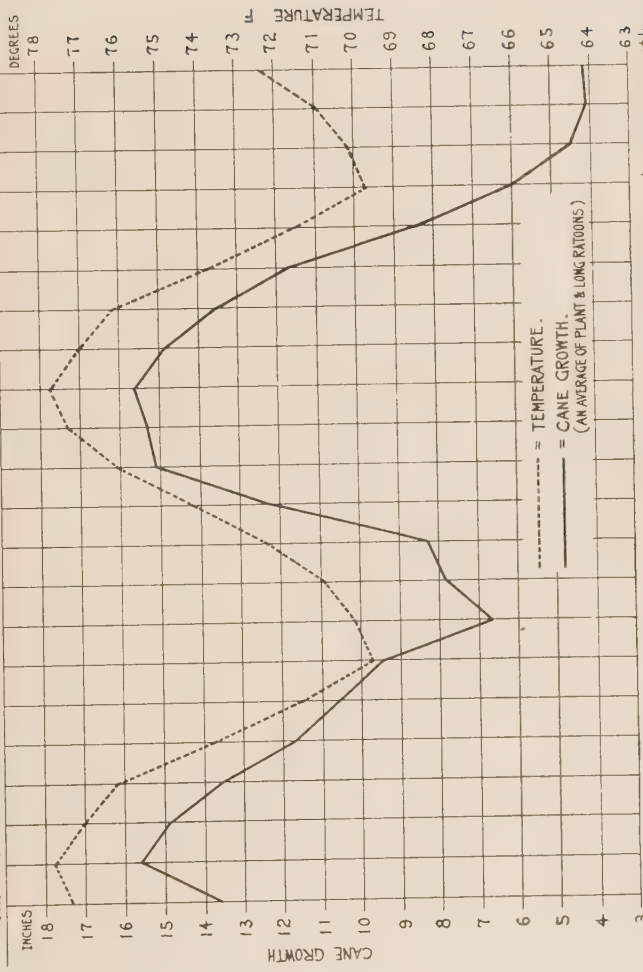

JULY AUG. SEP. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEP. OCT. NOV. DEC JAN. FEB. MAR. APR
INCHES
DEGREES
CANE GROWTH
TEMPERATURE °F
= TEMPERATURE.
= CANE GROWTH.
(AN AVERAGE OF PLANT & LONG RATOONS)

Fig. 1. Curve showing the correlation between temperature and cane growth measurement, data from Ewa Plantation Co., 1915-1919. In introducing certain corrections to the cane growth curve it does not conform so closely to the temperature curve as here shown, but takes a position to the left and towards the daylight curve.

from suitable varieties of cane and the control of pests and disease, and the equipment necessary for a going organization are: acres of land, man-days of labor, million gallons of water, pounds of nitrogen (etc., etc.), months of growing time."

A consideration of the possibilities of a more profitable use of growing time was omitted in introducing this subject for the sake of brevity. The report proceeded to show a simple mathematical interrelation between area, labor, water and fertilizers. It brought out the fact that some one of these essentials under any given set of conditions becomes the limiting factor in production and that waste occurs unless the other essentials are supplied in proportions measured to conform to the one that is available in limited degree. Where man-days of labor was the limited resource under the illustration set forth it was shown how sugar production could be increased or decreased by changing the proportions in which other essential factors, notably acres of land, were used. The report showed that, climatic conditions permitting, more sugar could be produced on a smaller area with a given amount of labor than on a larger area, and brought out the fact that: "Aside from increasing our total amount of labor and introducing labor-saving methods and devices, area reduction as a means of increasing yields offers the third opportunity for improving our sugar cane agriculture."

It is the purpose of this report to take up that essential of sugar production that the report of last year omitted for the sake of clarity and brevity, and to give consideration to growing-time and the significance to be attached to measuring its value.

Until a few years ago field yields were measured entirely upon an acreage basis. Several plantations now recognize the factor of time and we hear of "tons-of-sugar-per-acre-per-month" as a criterion for measuring yields. Some of us have found this a very useful agency in increasing our yields. George F. Renton, Jr., recently referred to it in a letter to the writer, suggesting that a uniform basis of calculation be employed by all using the term, He said, "It appears that the term is becoming popular and may become so popular as to be adopted by many of the plantations and given as a part of their field reports on account of the wealth of information it gives."

If, however, we find it profitable to take *time* into consideration and measure our yields on the basis of acre-months, may it not also be advantageous to study mathematically the relative value of *winter-time* against *summer-time,* and to denote or estimate the relative growing-time value of each month in the year; and, further, to devise a plan whereby we can use this information to increase our production of sugar.

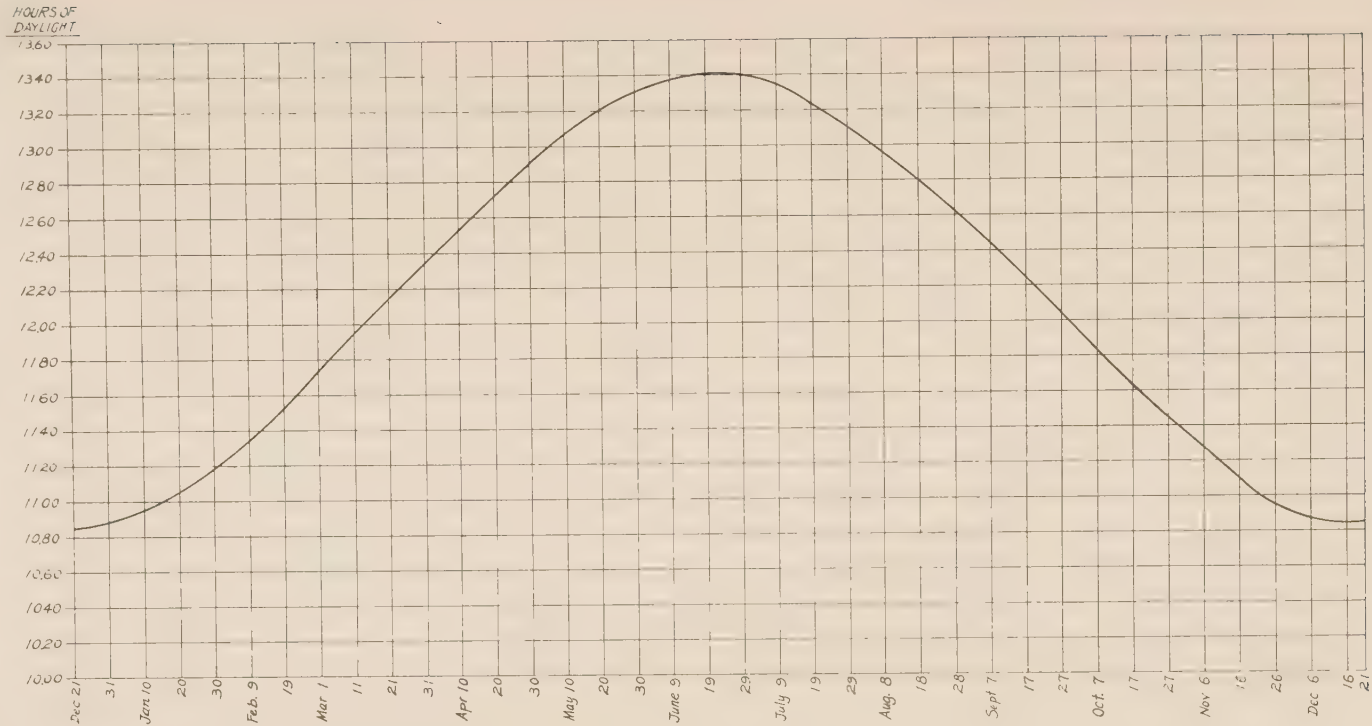


Fig. 2. This curve shows the variation in the hours of daylight throughout the period of one year.

A means of doing this is now submitted for your consideration.

In measuring damage due to the labor strikes in 1909 and again in 1920 the Experiment Station made use of some cane growth measurements to estimate the value of the time during which crops were neglected. In 1920, we paid special attention to cane stalk measurements taken by the Ewa Plantation Company over a period of several years. We also had growth measurements from the Kahuku Plantation Company which bore a close seasonal relation to the Ewa figures notwithstanding the difference in the total growth of the two places. Data and diagrams covering the subject were compiled by J. A. Verret. Some of these were later published by W. P. Alexander in his paper: "The Irrigation of Sugar Cane in Hawaii." They are reproduced here in Table A and Fig. 1.

TABLE "A"

	Increased Length of Well Developed Stalk in Inches
March	8.5
April	9.0
May	11.5
June	13.9
July	13.8
August	17.0
September	15.8
October	15.9
November	13.5
December	8.3
January	6.0
February	4.6
March	4.5
April	4.6

In short ratoons of fourteen months' growth the above values were obtained at Ewa Plantation in measuring cane growth.

A close study of these growth measurements has since revealed the need for certain minor corrections which, when applied, explain a few discrepancies and once these are removed we find, as will be shown, a relation between hours of daylight and degrees of cane growth which offer a satisfactory basis for practical estimations.

The correlation between the temperature and the growth curves is not actually as close as is shown in Fig. 1. The growth measurements used in this case considered the growth to a certain point on a well developed part of the cane sticks. The growth thus measured took place, in fact, several weeks prior to the temperatures with which it is compared. Cane growth, the actual

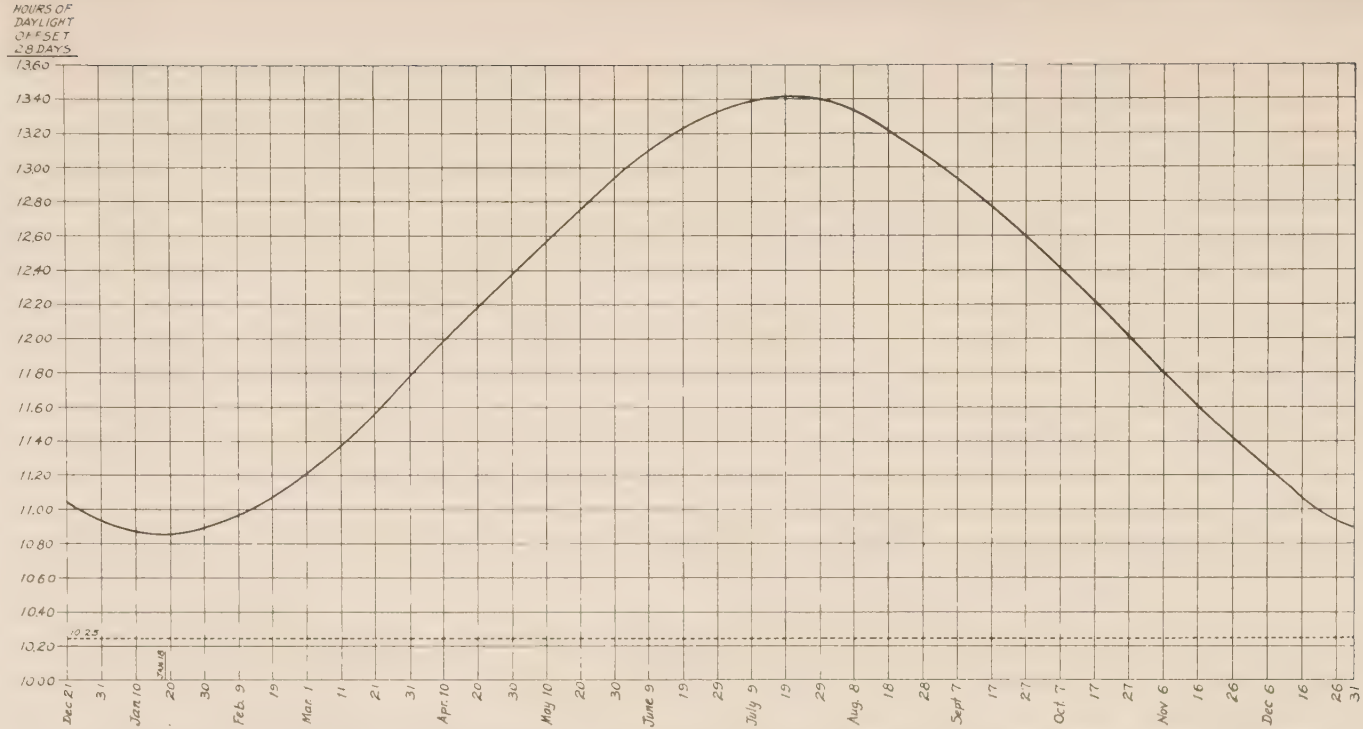


Fig. 3. The sugar cane growth curve here shown is the daylight curve advanced by twenty-eight days. It occupies a position midway, more or less, between the daylight curve and the temperature curve. The base line shown here at 10.25 gives a value to the January growth of 20 per cent of that of the July growth. The other months take their proportionate values accordingly.

elongation of the leaves and joints of a cane stalk, that takes place as a result of the light and temperature of today, is entirely within the green top. The way in which cane growth proceeds was fully demonstrated by Java investigators and an account of their work was reproduced in two publications* of the Station, and need not be repeated here.

If we set back by several weeks the growth curve in Fig. 1, we find that the peak of the growth curve no longer falls under the peak of the temperature curve. Since cane growth is influenced by both light and temperature it seems entirely reasonable that the position of the growth curve should be influenced by the position of the hours of daylight curve and the temperature curve as well.

The writer therefore decided to construct a daylight curve, and through the influence of such data as we now have or may later accumulate, to change or shift this curve to show the rate at which cane grows during different parts of the year.

The daylight curve for the 365 days of the year is shown in Fig. 2. It is constructed from data supplied from the Honolulu Weather Bureau, by Mr. Thomas Blair, giving the hours between sunrise and sunset. Beginning with December 21, the shortest day of the year, the daylight hours per day at ten-day intervals are shown in Table B.

TABLE "B"

ACTUAL HOURS OF LIGHT FOR THE DATES NAMED

Dec. 21—10.85 (shortest)	Apr. 30—12.90	Aug. 28—12.63
" 31—10.89	May 10—13.06	Sept. 7—12.43
Jan. 10—10.95	" 20—13.20	" 17—12.23
" 20—11.05	" 30—13.31	" 27—12.02
" 30—11.18	June 9—13.38	Oct. 7 11.83
Feb. 9—11.35	" 19—13.40	" 17—11.61
" 19—11.54	(" 21)-(13.42) (longest)	" 27—11.44
Mar. 1—11.75	" 29—13.40	Nov. 6—11.28
" 11—11.93	July 9—13.36	" 16—11.10
" 21—12.15	" 19—13.23	" 26—10.95
" 31—12.33	" 29—13.11	Dec. 6—10.90
Apr. 10—12.53	Aug. 8—12.98	" 16—10.86
" 20—12.74	" 18—12.80	" 21—10.85

* Hawaiian Planters' Record, Vol. XXVI, p. 143.
"Improvement of Cane Through Bud Selection," by A. D. Shamel, p. 13.

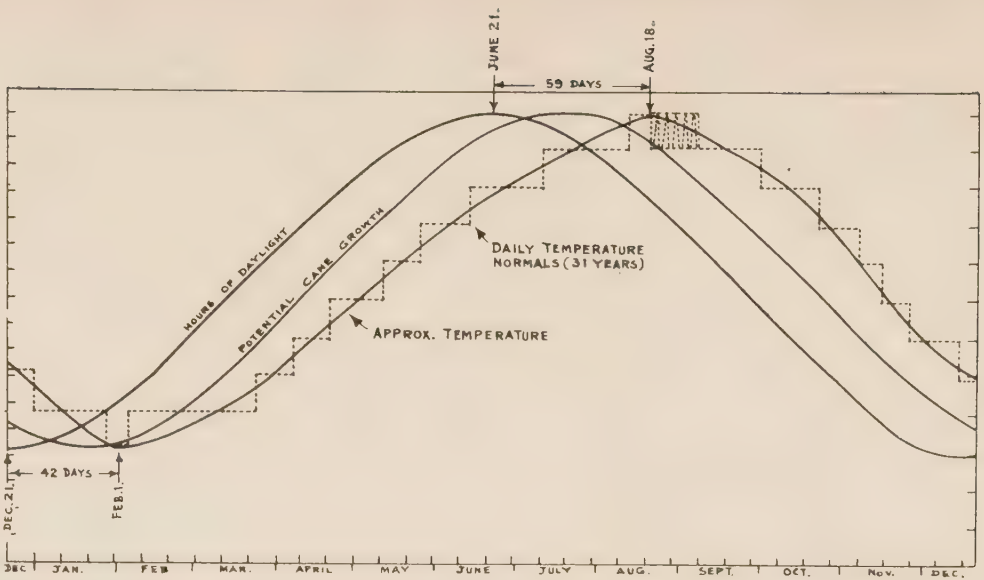


Fig. 4. Here we see the potential cane growth curve in comparison with the daylight curve and the temperature curve. The dotted lines are the daily normals of Honolulu furnished by the Weather Bureau and covering thirty-one years of data. The curve marked "approximate temperature" is simply another expression of the dotted line, omitting irregularities. The curve of potential cane growth as here shown is the daylight curve advanced by twenty-eight days and is the same curve shown in Fig. 3.

In a temperature curve based on the daily normals from thirty-one years of data at Honolulu, furnished by the Weather Bureau, the center of highest mean daily temperatures falls on or about August 18. The low point of such curve would fall on, or about, February 1; this is the center of low daily mean temperatures.

It is of interest to find that there is a difference of 59 days between the peak of the light curve and the peak of the daily mean temperature curve but only 42 days between the corresponding low points of these curves.

Possessed as we are with data and evidence that a curve constructed to show potential cane growth would fall to the left of the temperature curve and in all probability to the right of the daylight curve, it seems entirely reasonable to assume a growth curve about halfway between the temperature and the light curve.

We have for the purposes in hand adopted as a curve expressing the potential cane growth, the light curve offset by twenty-eight days. This furnishes a curve without irregularities that falls midway, more or less, between the temperature and the light curve and will, we feel, answer the requirements of the case (Fig. 3 and Fig. 4).

This curve is supported in a general way by cane growth measurements at Ewa, Kahuku and Makiki. The objection to using a curve founded entirely on cane growth measurements is that we do not have enough data to overcome the irregularities of such influences as soil, fertilizers, water, season, individual plant differences, age of the cane plant, etc., etc. The time to accumulate such data would run into decades. The most we can hope to have today is a theoretical curve, supported by such data as we have and subject to such small modifications as will be justi fied by our future investigations.

We will next consider how to give expression to the value of the growing time of the different months on the basis of this curve. The proposed schedule of values to be really useful must have general application over a wide range of conditions. To express the monthly values in tons of sugar per acre, or fractions thereof, would be to have a schedule too inelastic to meet the varying requirements of different districts or even different fields of the same plantation.

It was therefore decided to express the cane growth of one year by a circle of 360 degrees, and divide this circle into sections, which would express the value of the different months in angular degrees.

The sum of the offset daylight hours of the offset growth curve amounts for the year to 4,434 divided between the different month as shown in column I of the table C.

TABLE "C"

	I	II	III	IV	V	VI	VII	VIII
January	337.15	10.88	0.63	19.53	10.150	10	10	10
February	308.89	11.03	0.78	21.84	11.350	11	10	10
March	356.20	11.49	1.24	38.44	19.977	20	20	20
April	362.68	12.09	1.84	55.20	28.688	29	30	30
May	393.29	12.69	2.44	75.64	39.311	39	40	40
June	395.24	13.17	2.92	87.60	45.526	45	45	50
July	415.12	13.39	3.14	97.34	50.588	51	50	50
August	410.37	13.24	2.99	92.69	48.172	48	50	50
September	383.70	12.79	2.54	76.20	39.602	40	40	40
October	378.55	12.21	1.96	60.76	31.577	32	30	30
November	348.46	11.61	1.36	40.80	21.204	21	20	20
December	344.35	11.11	.86	26.66	13.855	14	15	10
Total	4,434.00				360.000	360	360	360

I—The total daylight hours offset by 28 days.

II—The average offset daylight hours. This value is obtained by dividing the value of Column I by the number of days in the month.

III—These values might be termed the "active" daylight hours per day. It is derived by subtracting the base line value 10.25 from the values in Column II.

IV—The total "active" daylight hours per month. These values are obtained by multiplying those of Column III by the number of days in each month.

V—The growth degrees. The values are obtained by converting those of Column IV to angular degrees.

VI—Growth degrees—whole numbers, the values of Column V, omitting fractions.

VII—Growth degrees, the values of Column VI expressed in 5's and 10's.

VIII—Growth degrees—round numbers, the values of Column VII expressed in 10's.

To obtain the average daily value for each month the monthly values are divided by the number of days in each month resulting in the daily values shown in column II.

With the highest values in July and the lowest in January we must now prepare to take care of different localities or fields by assuming that the ratio between the January growth and July growth is, for example, one to five.

A number of plantation men have been consulted and many find this an acceptable ratio for certain conditions. We will use this ratio, therefore, in explaining the development of the plan. At first thought it may seem extreme to assume that the January growth is only 20 per cent of the July growth. It must be borne

in mind, however, that slower growth expresses itself in three distinct ways, and these interact upon each other to an extent that is not fully appreciated until the situation is analyzed by a simple calculation.

(We find the rate of joint formation at Makiki to be about 9 or 10 days in the winter months against 4 or 5 in the summer, or about half. The joints formed in winter are shorter. This reduction is oftentimes fully 50 per cent or more. A reduction in the diameter of the stalk is frequently registered in the winter months as compared with summer. Since the volume, and therefore the weight, of cane varies with the square of the diameter, a small reduction in diameter not readily measured by the eye makes a big difference. We have for instance a difference in volume of 25 per cent between a diameter of 1.5 inch and 1.3 inch. The three discounts noted here, 50% and 50% and 25%, would in combination result in a total reduction of 81.25%.

The whole scheme we are about to outline can be recalculated on ratios of 3 to 10, 4 to 10, as well as 2 to 10, or where more adverse climatic conditions prevail ratios of 1 to 10 can be used or if need be January growth can be given a value of approximately zero. Such a state of affairs is no doubt encountered in practice on some of our coldest cane areas. More will be said later about the selection of the proper January-July ratio. Meanwhile the ratio of 1 to 5 may be accepted as fairly representative.

If, mathematically, we establish a base line for the growth curve that will introduce the proposed ratio of 1 to 5 between the January and July section of the curve we can then establish the potential growth value of each month of the year.

This base line has been drawn at 10.25 as shown in figure II.

(Let x=base line value
y=average height of January section of curve above base line
z=average height of July section of curve above base line

Then

$x+y=10.88$ (from column II table *C*)
$x+z=13.38$ (from column II table *C*)

But

$z=5\ y$ (in keeping with 1:5 ratio to be established)
$x+5\ y=13.39$

$$y=\frac{13.39-10.88}{4}=.63$$

Therefore

$x=10.88-.63=10.25$)

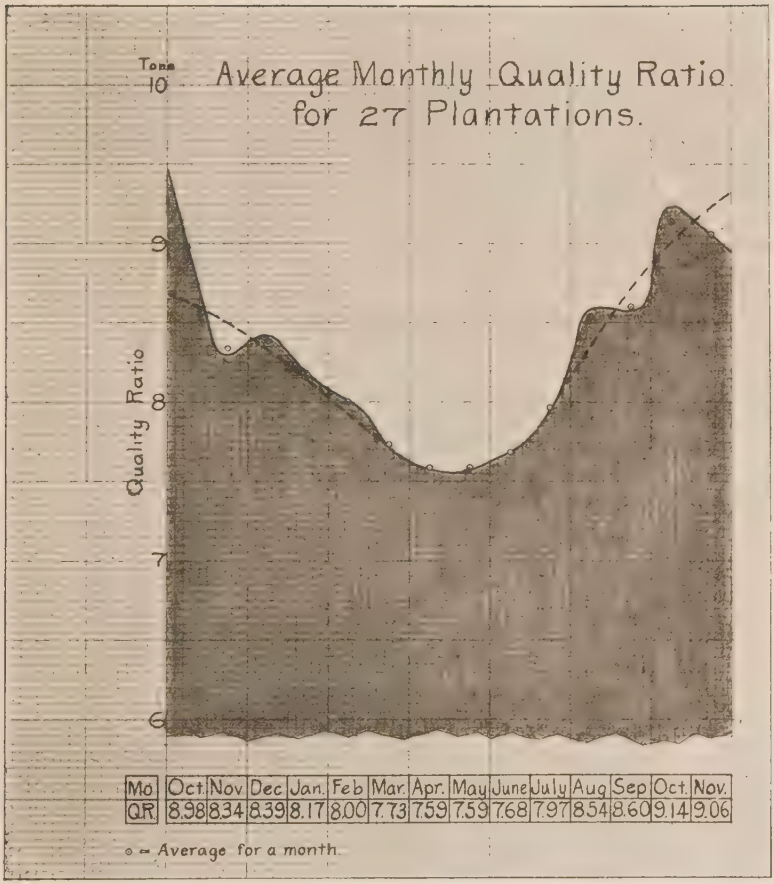

Tons
10
Average Monthly Quality Ratio
for 27 Plantations.
9
8
7
6
Quality Ratio
Mo. Oct. Nov. Dec Jan. Feb Mar. Apr. May June July Aug Sep Oct. Nov.
QR 8.98 8.34 8.39 8.17 8.00 7.73 7.59 7.59 7.68 7.97 8.54 8.60 9.14 9.06
o = Average for a month.

Fig. 5. The quality ratio curve from Circular No. 22, showing poorer juices as overripe cane is harvested after May. There is no essential difference in this curve in the case of irrigated and unirrigated plantations.

The relative growth value of the average day of each month is then the column II value less the base line value 10.25. The values of column III result. The monthly growth values are then the column III values multiplied by the number of days in each month, as per column IV.

The column IV values are then transposed to represent "growth degrees" for if the growth of one year is 360 degrees that of each month is the proportion thereof shown in column V.

Omitting small fractions for the sake of convenience we have the values of column VI, or we may express them in round numbers as in column VII, or even as in column VIII.

A comparison of the column VI, and column VIII values together with calculations made for studying the use of the two in practice, suggests that for an introductory study of growing time values we employ these round numbers to represent the growth values of the different months. They can be easily memorized and used in mental calculations. Beginning with January they are: 10–10–20–30–40–50–50–50–40–30–20–10. The winter months December, January and February are each rated as 10, the summer months June, July and August as 50, the spring months run 20–30–40 and the fall months, the reverse, 40–30–20.

Certain terms and definitions will facilitate a discussion of the subject:

1. *A growth-year* consists of 360 growth degrees and is the same as a calendar year.
2. *A growth-degree* represents 1/360 part of the growth of one year. There may be 10 growth-degrees to a calendar month or 50 depending on the season of the year.
3. *A growth-month* is 30 growth-degrees and differs from a calendar month in that it expresses 1/12 of a year's growth independently of the time consumed by that growth.
4. *An acre-month* is the area and time combination of one acre for one calendar month.
5. *An acre-growth-month* is the area and growth value combination of one acre for one growth-month.

Practical applications of treating cane growth on this basis is described in what follows.

Cropping Cycles:

An outstanding fault of the Hawaiian cropping system was brought out in Circular No. 22 showing the quality ratio curves throughout the harvest season. The average curve of 27 plantations is reproduced here (Fig. 5). The curves of individual plantations are available in the above named publication. The poor

quality of cane during the first part of the crop is due to immature cane, a brief period of mature cane is then harvested, after which overripeness is indicated by the upward trend of the curve. The two-year cropping cycle is wasteful in forcing upon a plantation the necessity of harvesting overripe cane during several months. The loss in quality of cane is great, but the loss of potential acre-growth-months on the new crop is oftentimes greater.

In order that the growth-degree values of the different months may be readily translated into sugar tonnage, Table D is provided giving the sugar tonnage equivalent for a range of conditions that is likely to embrace all cases. The average tons-of-sugar-per-acre-month value is shown together with the acre-year and acre-two-year equivalents.

TABLE "D"

Month	Growth-degrees	Tons-sugar-per-acre-month. .1	.2	.3	.4	.5	.6	.7
January	10	.03	.07	.10	.13	.17	.20	.23
February	10	.03	.07	.10	.13	.17	.20	.23
March	20	.07	.13	.20	.27	.33	.40	.47
April	30	.10	.20	.30	.40	.50	.60	.70
May	40	.13	.27	.40	.53	.67	.80	.93
June	50	.17	.33	.50	.67	.83	1.00	1.17
July	50	.17	.33	.50	.67	.83	1.00	1.17
August	50	.17	.33	.50	.67	.83	1.00	1.17
September	40	.13	.27	.40	.53	.67	.80	.93
October	30	.10	.20	.30	.40	.50	.60	.70
November	20	.07	.13	.20	.17	.33	.40	.47
December	10	.03	.07	.10	.13	.17	.20	.23
Acre-year equivalent		1.2	2.4	3.6	4.8	6.0	7.2	8.4
Acre-two-year equivalent		2.4	4.8	7.2	9.6	12.0	14.4	16.8

A table showing the value in sugar per acre for each month when the average tons of sugar per acre-month varies between .1 and .7. The acre-year and the acre-two-year equivalents are also shown

Where the average tonnage-per-acre-month is 0.5, it is important to note that this falls in winter to .17 and rises in the summer to .83. The knowledge that the three months of June, July and August have a potential growth value under certain conditions of 2.5 tons of sugar per acre should stimulate endeavor to realize in practice a high percentage of this potentiality.

Take the case of a field on an unirrigated plantation producing six tons in two years or .25 tons per acre-month. The quality ratio curves of plantations near Hilo show that the last two or

three months of the crop of a field harvested in August or September is idle time that has a potential value of .4 *ton* of sugar per month could it be used on the new crop. (On the irrigated plantations the situation is complicated by lack of irrigation water

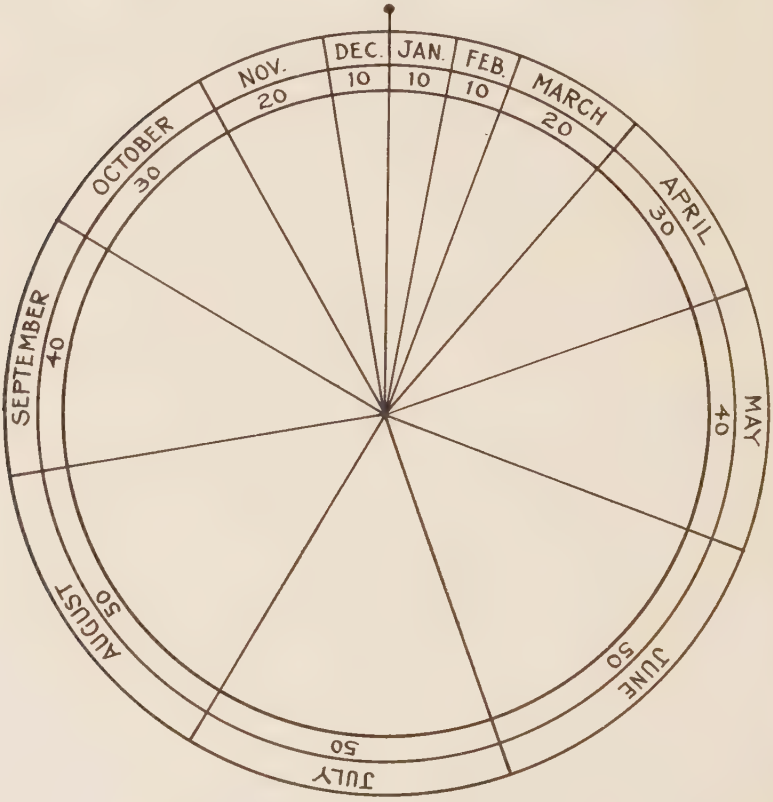


Fig. 6. Sugar cane growth calendar. The relative growing value of each month is expressed in angular degrees. In this case round numbers have been used and the January growth has been assumed to be 20 per cent of that of the July growth. For other ratios between July and January growth see the growth calendars in Figs 7 and 8.

to take full advantage of potential cane growth values. An analysis of such a case must be reserved for another time.)

Much discussion has been had in Hawaii during recent years regarding short and long cropping cycles with the result that

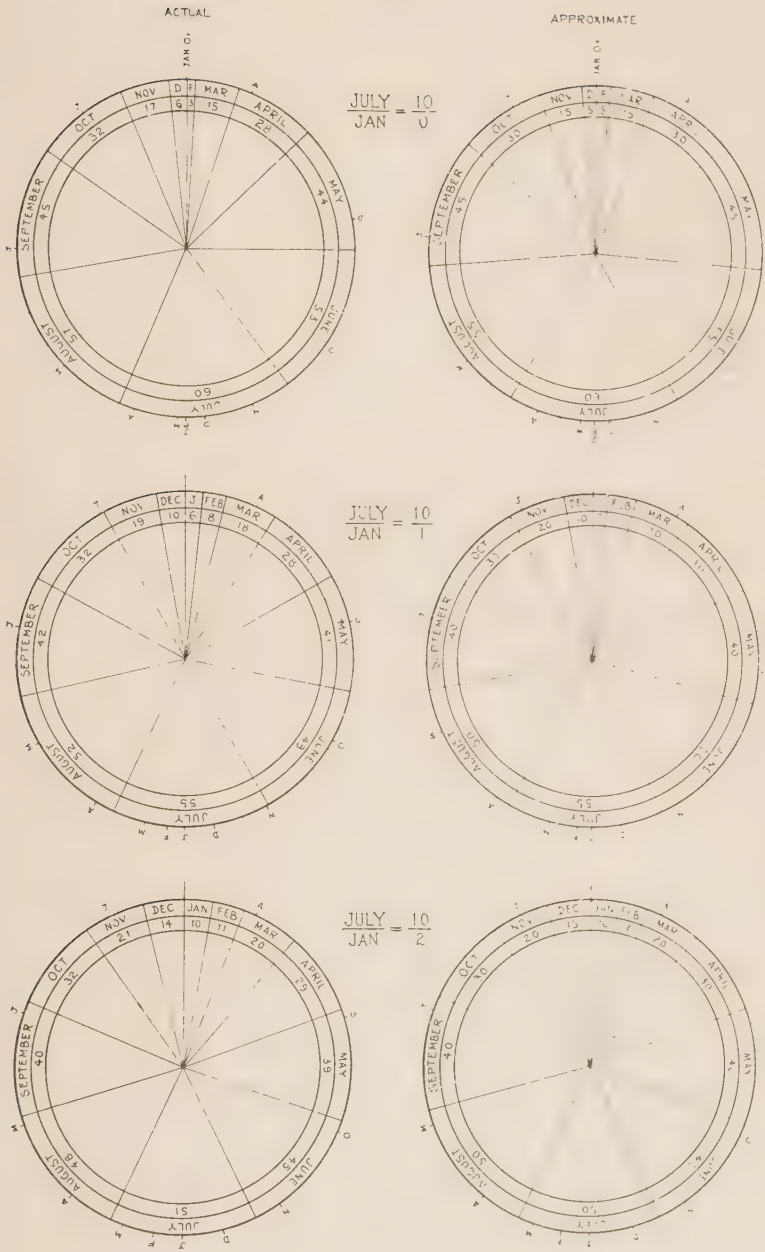

ACTUAL
APPROXIMATE
JULY / JAN = 10 / 0
JULY / JAN = 10 / 1
JULY / JAN = 10 / 2
JAN 0
NOV
DEC
JAN
FEB
MAR
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCT

Fig. 7.

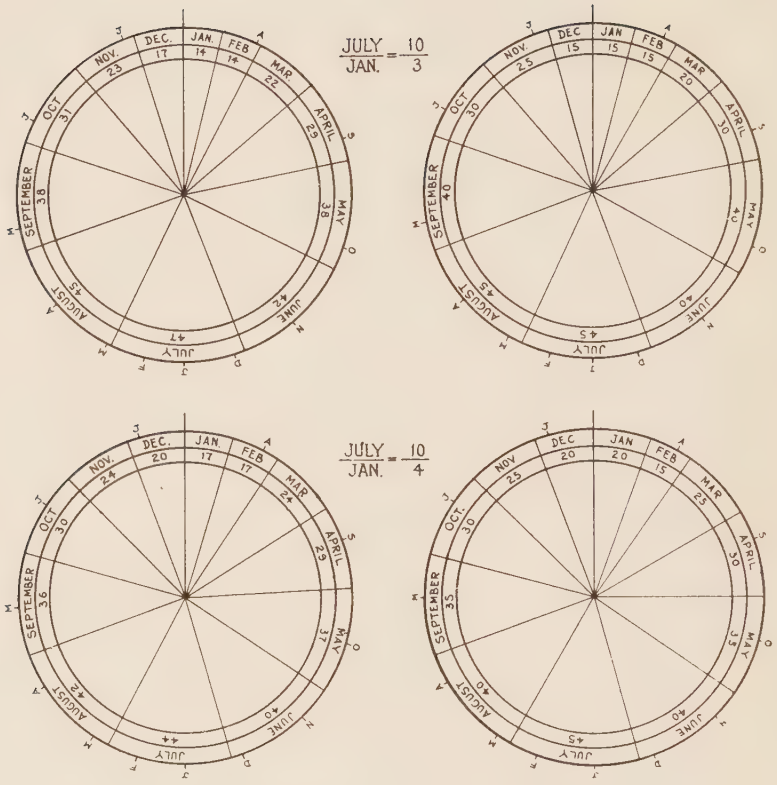


Fig. 8 (and 7). Sugar cane growth calendars. Those to the left show the actual calculated values in whole numbers. Those to the right, the approximate values in round numbers. The five sets of calendars represent a range of ratio of July and January growth as indicated.

several plantations are studying with interest the possibilities of a cycle of two crops in three years.

It is in ascertaining the efficient division of time between these two crops that a study of the growth values of different months assumes extreme importance.

A proper division of time on two crops in three years should result in little or no overripe cane being harvested. After May or June the harvesting proceeds with crops of the proper age and full value of the growing time can be realized.

An important point must not be overlooked in cropping cycles of two crops in three years. In two-year cycles two complete revolutions of the seasons take place. This is so whether we begin in January, March, June or August.

If, however, we start an eighteen month cycle in each of the months named a complex situation arises for, started in January, an eighteen-month crop would double on months of low growth value, while started in June we would double on months of the highest growth value.

By means of the sugar cane growth calendar shown in Fig. 6, we are, however, able to arrive readily at the right division of time for two crops in three years. We are concerned actually with a division of the three years into an equal number of growth-degrees. One year has 360 growth degrees, and three years have 1080. We want not two crops of 18 calendar months but two crops of 18 growth-months or 540 growth degrees. The term tons-of-sugar-per-acre-month, yet in its infancy, becomes obsolete in favor of tons-of-sugar-per-acre-*growth-month*. Having added time to area in measuring yields we go a step further and consider the growth value of that time.

Starting January 1, if we mark off 540 angular degrees by placing a straight edge along the left boundary of the January section we find the point where the straight edge intersects the circumference of the opposite side of the circle marks the date of division of two crops in a three-year cycle. The dividing line between equivalent cycles starting each month in the year can be determined in the same way. (The dates marking these divisions are shown in Figs 7 and 8 by the small spurs extending beyond the outer circle and lettered in each case to denote the starting month of the cycle.)

Disregarding small fractions of a month we find that cycles of 36 months should be divided into two crops as per the following schedule according to the month in which they start:

January	18.5+17.5=36
February	17.5+18.5=36
March	17. +19. =36
April	16.5+19.5=36
May	16. +20. =36
June	16. +20. =36
July	16.5+19.5=36
August	19. +17. =36
September	20. +16. =36
October	20. +16. =36
November	20. +16. =36
December	19. +17. =36

The suggestion is offered that the unirrigated plantation, now cropping its lands on a basis of one crop in two years, give consideration to a cropping schedule of two crops in three years for its best lands.

It is submitted that a fundamental resource of such a plantation is the *acre-growth-months* of its lands, as the term has been previously defined. When yields are expressed and compared in

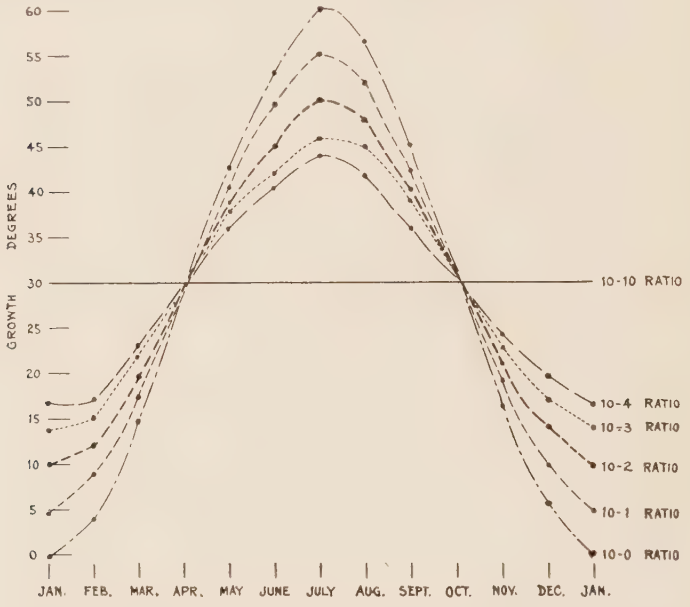


Fig. 9. If the year be represented by 360 growth degrees, cane growth, if there were no seasonal differences, would be represented by a straight line drawn at 30. As the value of the summer months exceeds that of the winter months, this cane growth becomes a curve which takes the various positions shown in the diagram, as the ratios of July growth to January growth vary between 10 to 4 and 10 to 0.

terms of acre-growth-months we will have a better means of gauging the efficiency of our agriculture. Potential growth-degrees are an asset that must enter into our field control of the future just as logically as tons-of-cane or tons-of-sucrose enter into our mill control of today.

It is as yet an open question as to how wide an application the ratio of 1:5 or 2:10 between January and July growth will have in practice. To aid in the study of this point and in the selection

of the ratio upon which to base other estimations the several ratios previously discussed are presented graphically for comparison in Figs. 7 and 8. These growth calendars for each ratio are shown on the left in actual calculated degrees and on the right in round numbers, to even five and tens, for such facility in use as may result.

If there were no seasonal influence the cane growth of a year, consisting of 360 growth-degrees, could be expressed by a straight line drawn across Fig. 9 at 30 growth-degrees. This line would represent a ratio of 1:1 or let us say 10:10 between winter and summer growth. As this ratio widens, or as summer growth exceeds winter growth, the straight line becomes a curve. Ratios between January and July growth of 4 to 10, 3 to 10, 2 to 10, 1 to 10 and 0 to 10 are displayed in the curves of Fig. 9. These curves are based on the monthly values calculated for each ratio in the manner already described.

Water, Fertilizers and Other Factors:

While customarily we consider the season of the year in its relation to irrigation and fertilization yet we have had until now no means of expressing the intervals between irrigations and fertilizations except by the ordinary calendar divisions of days, weeks and months. We shall have a clearer insight into these operations, if we think of these intervals in terms of growth-degrees. Cane requires water and nitrogen, we may assume, in direct proportion, more or less, to its rate of growth. The degree to which our fields are under-irrigated in summer, and the extent to which we tend to over-irrigate them in periods of low temperature and slow growth can be better understood when we chart these operations on a basis of potential cane growth instead of that of time.

Since on an average a ton of sugar is produced for each million gallons of water, we are now able to estimate the value of a million gallons of water applied at different parts of the year.

Since a ton of cane requires 3.5 to 4 pounds of nitrogen, we can now view the application of this nitrogen in terms that should enable us to distribute it with greater efficiency.

With a growth-degree perception of sugar cane agriculture we are better able in timing our field operations to approach a viewpoint that may be likened to that of the cane plant itself, rather than to be guided largely by the Gregorian calendar that differs so widely from the sugar cane growth-calendar.

Having estimated the value of growing time through the year we may undertake a study of these growth values in relation to water, fertilizer, land areas and man-days of labor. This cannot, however, be taken up at this time. A subsequent report will pre-

sent computations in this direction, and will include such deductions as may appropriately come from them.

In such a treatment of crop growth we are dealing with a subject that is new. There are, naturally, imperfections in this plan of viewing sugar production. These deficiencies, we venture to say, will prove to be far less than those which accompany the present system which takes little or no account of the values here discussed.

In proceeding with this work we wish to benefit by all the constructive criticism that can be brought to bear upon it from those who find interest in the plan. The subject is broad and, in some respects, intricate, but it holds possibilities that are well worth effort on the part of students of sugar technology. In short, we are beginning research work to ascertain the essential factors of sugar production, to evaluate them mathematically, and to study the interrelations of these values with the view of bringing to our agriculture at least some of the precision to which we have become so thoroughly accustomed in matters of chemistry and engineering.

Publications

The publication of the Record has been continued as a quarterly.

The Sugar Technology department has issued Weekly Mill reports, Commercial Sugar reports, and the Annual Synopsis of Mill Data. In the preparation of these publications Mr. McAllep has been greatly assisted by Mr. Brodie.

The Irrigation of Sugar Cane in Hawaii, by W. P. Alexander, was published in April. This paper was originally prepared as a thesis for a degree at the University of Hawaii and was published by us through the courtesy of that institution.

The Improvement of Sugar Cane Through Bud Selection, by A. D. Shamel, was published in January.

The following publications are now in the press:

Histological and Cytological Studies of the Fiji Disease of Sugar Cane. By L. O. Kunkel.

Further Studies on the Intracellular Bodies Associated with Certain Mosaic Diseases. By L. O. Kunkel.

Studies on the Mosaic of Sugar Cane. By L. O. Kunkel.

(The above papers will be brought out in one bulletin.)

Studies in North American Delphacidae (Homoptera), by F. Muir and W. M. Giffard.

A Study of the Phosphates in the Island Sugar Lands, by W. T. McGeorge.

Quality ratio data for a period of seven years has been compiled for publication under the supervision of W. L. McCleery.

Additions and Changes of Staff

The Pineapple department, established in 1922 and supported by the Association of Hawaiian Pineapple canners, became a separate institution in January, as the Experiment Station of the Association of Hawaiian Pineapple Canners, with R. E. Doty as director, and Messrs. W. A. Wendt and H. L. Denison, also formerly of this Station, as members of the staff.

The department of Plant Pathology, which became a branch of the department of Botany and Forestry when that department was created in 1918, was, in July, re-established as a separate department and negotiations are under way to appoint a staff which will include H. Atherton Lee, of the Philippines, as one of the pathologists.

Through the death of F. R. Werthmueller in January, the Station lost a valuable member of its staff. Mr. Werthmueller had been with the Station since May, 1902.

Another member of the staff, Miss Olive Fletcher, died in July. Miss Fletcher had taken the position as Laboratory Assistant in March, and through her training and experience would have contributed much to our work in plant pathology.

C. L. Crutchfield joined the staff as Assistant Chemist in January.

F. Ray Van Brocklin joined the staff as Assistant Chemist in July.

H. F. Bomonti resigned as Assistant Chemist in December.

Walter E. Smith joined the staff in December as Assistant Chemist in the Sugar Technology department, and was assigned to the raw sugar filtration investigation.

Reginald H. King joined the staff as Assistant Chemist in the Sugar Technology department in April.

E. L. Caum resigned as Assistant Pathologist in October.

Donald Forbes joined the staff as Superintendent of the Vineyard Street Nursery in November.

L. O. Kunkel resigned as Associate Pathologist in June, to accept a position with the Thompson Research Institute, of Yonkers, N. Y.

Frank W. Broadbent joined the staff as Assistant Agriculturist in March.

J. S. B. Pratt, Jr., joined the staff as Associate Agriculturist in December.

Neil Webster joined the staff as Assistant Agriculturist in November.

Raymond Conant joined the staff as Assistant Agriculturist in July.

W. W. G. Moir resigned as Assistant Agriculturist in October.

Twigg Smith joined the staff as Illustrator in September, he having been engaged since December on a part-time basis.

H. T. Osborn, whose services were transferred temporarily to the Board of Agriculture and Forestry for entomological work, under a joint arrangement with that Board, has returned to the Station staff and is continuing to carry on work in Mexico.

Respectfully submitted,

Experiment Station, H. S. P. A.
H. P. Agee,
Director.

APPENDIX

Laboratory Work

Statistics bearing upon the work of the chemical laboratory are given as follows. In handling that part of the work which pertains to his department, Mr. McAllep was assisted by Messrs. W. L. McCleery, A. Brodie, H. A. Cook, W. E. Smith and R. H. King. In the chemistry department, Mr. Stewart was assisted by Messrs. W. T. McGeorge, E. C. Thomas and Fred Hansson.

Fertilizer Control Work

The fertilizer samples included in this report, cover the work for the past twelve months period up to the 30th of September. During this time 262 fertilizer samples have been analyzed, representing 19,291¾ tons. Of these samples 214 representing 13,377¾ tons were sampled in Honolulu and 48 samples representing 5,914 tons and 15 bags were sampled by our representatives in San Francisco.

There were 33 samples deficient. These samples showed an indicated rebate of $3,169.98. Of these samples 27 were from Honolulu with a rebate of $2,239.98 and 7 were from San Francisco with a rebate of $829.66. The Honolulu samples represented 1,710 tons and the San Francisco, 857¼ tons.

The work on the fertilizer samples during the past year has shown a better agreement between the guarantees and the manufactured product than was found during the previous season. Some variations will ordinarily occur, due to lack of uniformity in the raw products. Our system of control undoubtedly aids in keeping these fluctuations down to the minimum.

FERTILIZERS		
Complete Fertilizers Reported	226	
Agents' Reserve	10	
Potash Nitrate	33	
Sulfate—Nitrate Mix.	6	
Superphosphate	3	
Repetitions	126	
		404
MISCELLANEOUS WORK		
Ammonium Nitrate	2	
Ammonium Phosphate	5	
Bagasse Ash	1	
Barium Carbonate	2	
Cotton Seed Cake	1	

Fertilizers	6	
Flue Ash	2	
Limes	3	
Molasses	1	
Molasses Ash	2	
Molasses Mash	3	
Molasses Nitrogen	24	
Mud Press	4	
Nitrate of Lime	3	
Nitrate of Soda	1	
Phosphate Rock	2	
Plant Stimulant	1	
Potash	2	
Soil	1	
Trash Compost	4	
Waters	15	
		85

PINEAPPLE WORK, MISCELLANEOUS

Bone Meal	2	
Canned Pineapple	30	
Dried Blood	3	
Fertilizers	7	
Mud and Waste Waters	12	
Phosphoric Acid Solutions	3	
Pineapple Fruits and Juices	17	
Pineapple Juices	10	
Pineapple Syrups	2	
Soil (complete analysis)	1	
Soil Stimulant	1	
Waters	6	
White Sugar	1	
		95

PINEAPPLE WORK INVESTIGATIONS	
Soils, Nitrification, Plant Analyses, etc	1,128
CHEMICAL WORK INVESTIGATIONS	
Determinations on Research Problems	10,079
TOTAL CHEMICAL AND PINEAPPLE WORK	11,791

WORK OF THE SUGAR TECHNOLOGY LABORATORY
OCT. 1, 1922, TO SEPT. 30, 1923

Analytical Weights Standardized	3
Brix Hydrometers Calibrated	168
Cane Juice from Uba Cane	1
Cane Juice, Phosphoric Acid	7
Deposits on Electrodes	2
Evaporator Scale	1
Kopke Centrifugal Mud	2
Juices from Field Tests	3,083
Lime	2
Lime Rock	5
Fuel Oils	46

Massecuites	18
Molasses	110
Molasses Ash	1
Polariscopes Cleaned and Adjusted	8
Polariscopes Examined	1
Polariscope Cover Glasses Tested	31
Polariscope Tube Repaired	1
Polariscope Tubes Tested	10
Press Cake	1
Quartz Plate Checked	1
Refractometer Cleaned and Adjusted	1
Sugar Analyzed	166
Sugar Analyzed (Insoluble Solids)	11
Sugar Polarized	149
Sugar Grain Separation	525
Sugars Tested for Salt	704
Sugar Weights Adjusted	2
	4,992
Determinations in Research Work	5,342
TOTAL	11,406